Climate

The Scientific Roll.

A BIBLIOGRAPHY, GUIDE AND INDEX TO CLIMATE.

BY

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THE SCIENTIFIC ROLL

AND

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INTRODUCTION.

1. CAPTAIN CUTTLE'S recommendation to make a note of a fact, when once it has been found, has long since passed into a familiar and well-approved-of by-word. The full advantage of the operation, however, is not obtained until the note made has been put where it can be easily referred to again whenever wanted.

2. Scientific literature has long since become an immense storehouse of facts, the contents of which are so arranged that in many cases it is very difficult indeed to find the individual statement wished for. Every year the difficulty increases, and efforts are made from time to time to meet it by means of records, annuals, classified catalogues, digests and indexes. These works are unquestionably useful, and all honour is due to those who have conceived and executed them; but the principles upon which they are based do not seem calculated to supply the great desideratum, viz. a simple, uniformly arranged key to, and summary of, science.

3. A plan for effecting this is here proposed. It is to thoroughly search each paper or volume and arrange its contents under specified headings classified according to a definite order. In this way the information supplied by that particular paper or volume is placed within easy reach of everyone. By extending this process to other papers and volumes, fresh facts are obtained and classified. The larger the area of literature the process is applied to, the more useful becomes the collection of systematised notes. When a large number of books have been thus treated, the analyser finds that owing to repetition each additional work which is examined contains comparatively little that has not already been entered in the notes. The systematisation of notes, hence, necessarily results in the most compendious condensation and concentration possible of all that is wanted in scientific literature, so arranged that, generally, any particular fact would be far more accessible in its new position than where it was originally placed.

4. The 'SCIENTIFIC ROLL' will endeavour to develope this idea. It would be impossible to complete the task without a great deal of organised co-operation. Still it is hoped that the beginning here offered will be found sufficiently useful to lead to the plan being carried out on a larger and more efficient scale. When it is considered that there are upwards of six thousand distinct scientific serials it will be manifest that the 'SCIENTIFIC ROLL' does not claim to make any approach to completeness, except in so far as relates to the books or articles which are marked as having been read.

5. Notes thus collected may have a somewhat disconnected appearance so far as the want of fluency of language is concerned, but the contiguous statements usually have such a close connection with each other that the flow of ideas is unexpectedly even, so that not only are lines of thought suggested, but facilities are offered for following them out, which books as a rule do not afford.

6. An opportunity will be taken at a later period for giving a full explanation of the system developed in the following pages. Here, however, it may be mentioned that although passages are often taken verbatim, quotation marks are not given. In all cases the endeavour is to give the substantial meaning as briefly as possible; so that when it happens that to follow the actual words of the author would be useless verbosity, the passage is summarised. No attempt is made at altering the sense, or correcting mistakes of fact or spelling, or modifying anything which bears upon the subject of the heading Everything unconnected with the subject under consideration for the time is omitted. Hence it will be clear that for purposes of quotation the original work must be consulted. Correction of errors, comments and explanatory remarks by the Conductor or his coadjutors, will invariably be placed in footnotes.

7. Considerable help has been afforded by the Royal Society's Catalogue of Scientific Papers, *Nature*, and many other useful repertories. Full acknowledgments of this kind will be made at the close of each section of the work. The matter is mentioned here because in the case of titles, and such like data, it would be inconvenient and unusual to cite the work whose authority is relied on for them. Many of the titles have been independently verified.

8. Explanations of the contractions used will be given in due course. One or two, however, require elucidation now. Every item, whether it be a paper, or a volume, or a series which has been examined and the facts afforded by it placed in the notes, is marked *ra* if the article only has been read; *rv* if the volume has been analysed; and *rs* if the series has been searched; but when such item has been read too late for the insertion of the facts in their proper place in a previously published part of the magazine, it will be marked *rp*.

9. Authors desirous of securing a notice of their publications will be conferring a favour by sending a copy of them to the Conductor, which will be returned to them, if desired, as soon as they have been analysed. Publishers and authors are respectfully asked to send early notice of all publications bearing upon meteorology, as by so doing they will enable the Conductor to incorporate the most recently published works.

ESSAY I.

ON THE DIURNAL PERIODICITY.

1. THE local weather changes are often and in many places so frequent and so abrupt that many nations have regarded the observed succession of cold and heat; of rain, snow, hail, storms of wind, and of fine weather; of electrical disturbance and of electrical calm, as almost matters of chance. Indeed the changes of the weather are commonly referred to as typical of fickleness. In other cases, where a number of laws have worked together for the production of a single event, individuals are prone to say that chance, not law, has brought it about. The knocking-down of a person by a vehicle in the crowded streets of a city; the so-called trifling events which accompany the perpetration of a crime or the achievement of a national blessing; the arrangement of the stones on a pebble beach or of the stars in the heavens; the collocation of two or three individual particles in this or that particular muscle or other organised structure; the event of two black balls being drawn from a heap of a 1000 balls, 500 of which are black, and 500 white—all these, and countless other examples which the reader can easily supply, are said to be (to a greater or less degree) dependent upon chance. But when each individual case is followed out in detail and the cases of the like kind are grouped together, then the larger the number of examples forming each group the more evidently are the laws which governed its occurrence made manifest. Thus with reference to the persons who are knocked down by vehicles in the streets of London, the active concomitants are so regular that it is possible to say beforehand, with a near apprcach to accuracy, how many persons will be run over in the ensuing week, and what proportion the fatal injuries will bear to those which are not fatal. The degree of accuracy of the prediction will depend upon the fulness of the knowledge possessed of the concurrent circumstances which produce such accidents. And so it is with the other illustrative instances mentioned. The arrangement of the pebbles upon a beach is undoubtedly the result of the action of many definite laws, and so also, scientific faith compels us to believe, are the mazy arrangements of the starry hosts of heaven and of the countless molecules of matter.

2. As then the rational grouping of like circumstantialities enables the statistician to discern law where chance is ordinarily supposed to prevail, so the methodical grouping of facts will allow of the deduction of conclusions which would not have been revealed by the scattered facts. Scientific faith constrains us to admit that law, not chance, reigns over the succession of the least, as well as of the most, striking of the weather phenomena. In proportion as knowledge increases so will faith change into a firmer and firmer conviction that law prevails in these phenomena; and doubtless with perfect knowledge there would be absolute conviction that there is no such thing as chance. Then, indeed, it would be felt that only two positions can be consistently maintained—the one is that everything is a matter of chance, the other that everything is a matter of law; or, in other words, that the universe is under the rule of nothing (which is tantamount to saying it is under no rule at all), or the rule of God. There is no middle position, so that when anything is said to happen by chance, the meaning must be understood to be that it happens according to certain laws, but owing to ignorance of those laws, the how and the why such a thing has happened is beyond the present condition of our understanding.

3. Of late years weather knowledge has made such important advances, that the perusal of a few pages will probably leave an impression on the mind of the reader that there are weather laws, and that meteorological science will become as definite as many of the more advanced sciences.

4. In the present essay the purpose is simply to allude to some facts which indicate the existence of a diurnal periodicity, that is, of a complete succession of climatic events which runs its course within a period of twenty-four hours. The variations which this periodicity may present according to place, and the causes which actually and apparently bring about these variations, will be left for further consideration.

5. The sun is, or appears to be, the great factor in climate; and the relative positions and movements of the earth and sun seem to be most intimately connected with the most prominent climatic periodicities. But there are also periodicities dependent upon other causes, which causes probably are the movements and positions of the moon and planets relatively to each other as well as to the earth, the sun and space, and the changes which are slowly worked out from age to age in the physical geography of the earth itself. But further allusion to these is unnecessary, as the movement of the earth with respect to the sun is, to all appearance, the chief, if not the only, operating cause of the diurnal periodicity.

6. In consequence of the earth's rotation on its axis the sun appears on the eastern horizon in the lower latitudes, gradually ascends to its highest point in the heavens, then descends to its setting on the western horizon, and remains invisible for a time until it has completed its circuit by reappearing on the eastern horizon. This circuit is effected in twenty-four hours. On and near the equator the days and nights are of equal length all the year round, but as we advance towards the poles the apparent motion of the sun in the sky declines from the vertical plane so that the relative lengths of the day and night fluctuate about the two poles of equality at the spring and autumn equinoxes; the days wax longer from the spring equinox till midsummer, and then wane to the autumn equinox. Then the nights become longer than the days, increasing in length till midwinter; after which they shorten again till the spring equinox. The degree of maximum inequality between daylight and darkness increases as we proceed pole-wards. Beyond the polar circles the duration of the presence or absence of the sun extends over more than twenty-four hours, so that the diurnal period vanishes for a portion of the year. The proportion of the year during which this diurnal movement is non-apparent increases until at and near the poles the apparent solar motion has become horizontal, and the periods of sun-presence and sun-absence are six months in length. In the north hemisphere the diurnal movement is from the left to the right of the observer, while in the south hemisphere the direction is from right to left. Thus although the earth rotates on its axis once in twenty-four hours, the oblique position of that axis, relatively to the position of the sun's axis in space, causes the length of the longest day to increase from twelve hours to six months during one half of the year, and to decrease from twelve hours to zero during the other half. The two hemispheres stand in opposite relations to each other as regards daylight, so that if we select two antipodal places the mean time during which the sun is above the horizon is twelve hours on every day in the year. So again, if we take the mean duration of sun-presence on two days six months apart, it will be found to be twelve hours all the year round.

7. In the preceding paragraph attention has been restricted to the supra-horizontal presence of the sun, but the remarks are so manifestly applicable to light that no observations with instruments are required to convince us that light, as a climatal element, has a periodicity of the same kind; and that the occasional occurrence of dark days in consequence of fogs, showers of volcanic ashes, flights of insects, and other circumstances, does not obscure the evidence.

8. As light and heat are close companions it might be presumed that temperature is subject to similar alternations; but in this case instrumental observations have been made in abundance, and the mind feels the need of other evidence than what is afforded by general scrutiny. The theoretical alternations in the intensity of light may be inferred from the movements of the sun, but practically the actual periodicity differs somewhat from the theoretical owing to the refractive power of the atmosphere and to various local circumstances. The theoretical annual mean would occur at the equinoxes and would be represented by a curve with arms of equal gradient and with six hours above and six hours below the mean. The graphic representation, then, of a semi-diurnal periodicity of twelve hours consists of a single hump with slopes of equal gradient, as in Fig. 1. As the duration of light each day increases, the hump will broaden and its height lessen in proportion to the lessened maximum intensity of the light, until with a diurnal periodicity of almost twenty-four hours the curve would be represented graphically by a broad hump with gradients less than those shown on the equinoxial curve; while in this flatter curve about twelve hours would be above, and twelve below, the mean, as shown in Fig. 2. In this case the means would be at 6 A.M. and 6 P.M. If the increment and decrement were equal for equal portions of time, the lines would be straight; but as the changes are modified in rate by the thickness of air through which the rays pass, the lines assume a curved form.

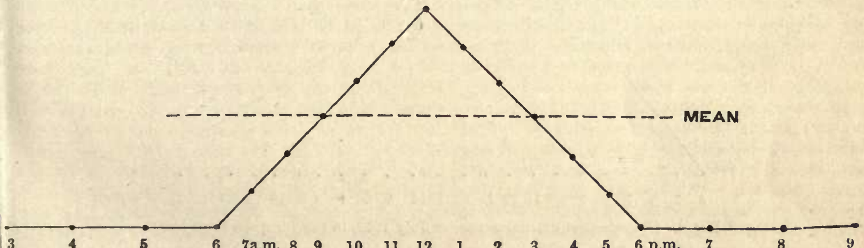

Fig. 1. Theoretical semi-diurnal line.

9. The heat which is supplied by the sun during the day is absorbed by the ground and by the air resting upon it, and is retained by them after the sun has set. There is usually a loss of a portion of this absorbed heat during the night, but in most instances such loss is gradual, so that the accession of heat during

the day has a greater and more prolonged influence on the nocturnal temperature than the daylight has upon the succeeding period of darkness. Hence the increase and decrease of heat normally extends over the whole twenty-four hours, thus giving rise to a diurnal periodicity. In the construction of diurnal curves it is important to bear in mind that the observations should be such as have been taken at times equal-distanced apart over the whole twenty-four hours, and that those times should embrace the epochs of maximum and minimum range. This matter is not of material importance when the object is simply to trace the existence of a diurnal periodicity; but it is essential when the rate of increase and decrease at different localities has to be determined. The point is mentioned here because it has been desirable to utilise observations which suffice for drawing a portion of the diurnal curve in the formation of a complete curve. For instance, Erskine made some observations in July 1868, on the line of the southern tropic in Africa which gave a mean of 73° Fahr. at 9 A.M.; of 79° at noon; and of 88° at 3 P.M. These figures taken by themselves are of little or no value for the present purpose. They indicate a rise from 9 A.M. to 3 P.M. without giving any clue to the times or degrees of the maximum and minimum temperatures. From 9 A.M. to noon the rate of increase is 2° per hour, and from noon to 3 P.M. it is 3°. So far as it goes the evidence would induce us to infer there was a continuous rise up to 3 P.M., and possibly beyond that hour. Incidental mention is made that the temperature of the water is 64°; but the hour of observation is not stated, and a guess has to be hazarded that the water is river water. The minimum, then, would presumably be below 64°. In July 1869, Baines collected some thermometrical data in about the same district, the value of which is diminished owing to want of information as to the hours; but as he records the highest and lowest temperatures observed, these help to supply the deficiency in Erskine's figures. The mean of the maximum temperatures is 77° and of the minimum not above 40°. In a subsequent journey through the Limpopo basin, where his former explorations were, Erskine notices that from March 6, the mornings became so cold that the blankets which had been discarded since September were again brought into use. From these scattered materials we are able to infer that the mean night minimum temperature in July in certain parts of the Limpopo basin is not above 40°. Assuming this to be so, and that the moment of minimum cold is shortly before sunrise, the following diurnal curve may be drawn. It is not to be imagined that such a curve is more than a rough approximation to the truth; but these particulars are given to show how scattered isolated notes may have their value enhanced by being placed side by side. The reason why these special figures were taken is because wishing to show proof of the existence of a diurnal periodicity of temperature on the line of the southern tropic of Africa, no better evidence was readily to be found, and these had been collected and systematised. All were found in less than half an hour. Facts, however, are not wanting which will suffice to show that there is unquestionably a diurnal periodicity of temperature in the inter-tropical region of Africa. Watson made observations at Rigaf in December 1874. This locality is in 4° 44′ 32″ N. lat. The mean temperature at 9 A.M. was 82·8°; at 3 P.M. 94°; and at 6 P.M. 82°; the mean maximum in the day was 95°, and the mean minimum at night 69·5°. The maximum was clearly not at 3 P.M.; but judging from analogy and the probabilities of the case it was before rather than after that hour. The increase and decrease of temperature was markedly regular. The range during the

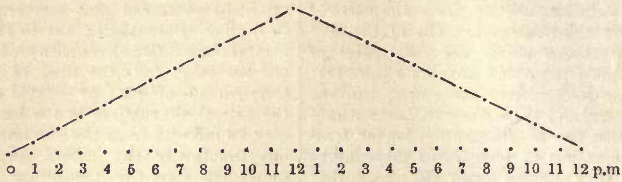

Fig. 2. Theoretical diurnal line.

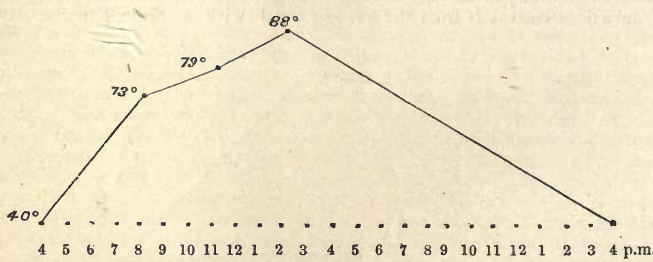

Fig. 3. Hypothetical diurnal curve for July 1878, in the Limpopo river basin.

twenty-four hours varied from 30° to 39°, but at the specified hours it never exceeded 9°. According to Skertchley the average daily temperature in Wassaw, a territory on the Gold Coast which lies between 5° and 6° N. lat., is 75° Fahr., and that of the night 65°. On the Victoria river in Australia, at 15° 30′ S. lat., Wilson found that the minimum temperature occurred about an hour before sunrise; and that the records for nine months gave an average of 72·8° at 6 A.M.; 92·3° at 1 P.M.; and 85·5° at 6 P.M. On the lower Amazon, as at Para, which lies close to the equator, the temperature is remarkably equable, the mean daily temperature according to Orton's observations being 80·2°. The maximum is reached at 2 P.M. and the nights are invariably cool. At Quito, where Orton stayed for a time and registered the thermometric readings, the temperature is very equable. Like Para it is situated close to the equator, but the heat is much moderated owing to its great elevation above the sea. The range in the twenty-four hours is about 10°; the coldest hour is at 6 A.M., and the warmest between 2 and 3 P.M. At Paca-yacu, in Ecuador, Spruce observed the minimum temperature to occur at 6.30 A.M., when it was generally 68°; the maximum was reached at from 2 to 3 P.M., when the temperature usually rose to 81°. At Trevandrum, in S. India, between 8° and 9° N. lat., the mean annual daily temperature rises from a minimum of 74° between 5 and 6 A.M., ascends to 85° at 1 P.M., and then sinks to 76° at midnight. In New Guinea, a little south of the equator, the temperature during the northern summer changes little during the day, but the nights are cold. In June the temperature on the Octanata river, as recorded by Dr. S. Müller in 1828, was 77° in the morning just before sunrise, 84° at noon, and about 78·4° towards evening. These illustrations from tropical localities, and were it necessary many others could be cited, all showing the same general feature, plainly manifest a diurnal thermic periodicity. No exceptions whatever are known. There are differences in the rate and extent of the increase and decrease of the temperature according to locality, but such differences do not in any way obscure the evidence. As a general rule the daily maximum in equatorial regions exceeds the minimum by about 5° on the land, but not more than 2° or 3° on the sea. On the land the maximum is reached between two and three in the afternoon; but at sea, at or soon after midday; while both on land and at sea the minimum occurs a short time before the sun rises. Recurring then to the observations made by Erskine, it may reasonably be conjectured that the 3 P.M. data should be placed not on the rising curve, but on the downward slope just beyond the turn. In other words, the maximum was probably 89° or 90° soon after 2 P.M.

10. In the regions between the tropics and the circumpolar circles the available observations are more numerous, precise, and reliable. A few selected instances need only be given here. Rüppell made observations at Gondar, in Abyssinia, during the winter of 1832–3. The means were 57·5° at 5.40 A.M.; 68·5 at 9.6 A.M; 75·8° at 12.30 P.M.; and 74·3° at 3.33 P.M. In all probability the maximum was before 3 P.M., but is not shown here; the temperatures at 9 P.M. and midnight are also required to be known for the ascertainment of the true diurnal progression of temperature. At Plymouth the mean annual daily temperature starts from a minimum of 47° Fahr. between 4 and 5 A.M., rises to the maximum of 55° between 1 and 2 P.M., and, declining to 47° at midnight, slowly sinks to the minimum. At the Stonyhurst observatory, Blackburn, in Lancashire, the hour of daily maximum ranges from noon in December to 4 P.M. in June and July, and, indeed, at most places the hour of maximum varies more or less with the length of the day. At Paris the average annual daily temperature is at its maximum at 2 P.M., being 58° Fahr.; the minimum is 44·8° at 4 A.M.; and the mean, 51·3°, occurs at 8.20 A.M. and 8.20 P.M. The observations made by Hayward in January 1869, at Yarkand, in Tibet, gave the following averages:—

Sunrise	13° Fahr.
9 A.M.	21°
Noon	29°
3 P.M.	31°
6 P.M.	27°
9 P.M.	23°

The time of the minimum, as well as of the maximum, varies according to the length of the day in the middle latitudes; the minimum occurring earlier in proportion as the days lengthen, while the maximum gradually becomes later as the evening light is extended.

11. The evidence harmonises well with what has been stated with respect to the duration of light. All the facts tend to show that the rise and fall of daily temperature is so far dependent upon the presence and position of the sun, and the rotation of the earth upon its axis, that a marked diurnal periodicity is plainly discernible wherever night and day follow each other during each rotation of the earth. In the Polar regions there is a periodicity of the same kind, although it is not so decided as in the lower latitudes. This is shown by the observations made on board the *Erebus* and *Terror* while cruising in the Southern summers of 1841, 1842, and 1843, between 60° and 78° S. lat. The figures are those given by Moseley.

4 A.M	28·795°
8 A.M.	30·065°
Noon	31·540°
4 P.M.	31·594°
8 P.M	28·956°
Midn.	28·892°

The hours selected were not likely to show the maximum; this probably occurred between noon and 4 P.M., and if anything nearer 4 than noon.

12. The foregoing results are based upon the facts afforded by thermometers placed a short distance above the ground, and therefore must be accepted as applying to that level only; because

from the investigations of Dines, Hamberg, and Glaisher, as well as from certain casual observations made by meteorologists and others on the appearance and disappearance of clouds, there is known to be a diurnal periodicity in the vertical distribution of temperature, the maxima and minima of which occur at different hours from those already noticed. Nevertheless the evidence is conformable and consistent. The temperature varies with elevation above the ground, and passes through a complete succession of variations in the course of each twenty-four hours. The observations made render it probable, it might be said almost certain, that during the hotter hours of the day the temperature decreases with elevation above the ground, while it increases with elevation during the cooler hours of the night. The rate of increase seems to bear some proportion to the radiation of heat from the ground, while the decrease bears a similar relation to the radiant power of the sun on the ground. According to Dr. Hamberg the lowest strata of the air are the coolest from two to three hours before sunset to at least two or three hours after sunrise. Glaisher infers from observations made by him at different levels from 22 feet above the ground and less that the higher strata are the warmer at night throughout the year in England; that this phenomenon extends to the afternoon hours in March, September, and October, and to all the hours of the day in January, February, November, and December. Burton and other travellers have remarked that the natives of Africa and other countries habitually encamp on slightly elevated spots for the purpose of avoiding the cold of the lower situations, and gardeners have frequently noticed with surprise that, during severe frosts, the plants above a certain height have escaped injury thereby, owing to this law of increase of temperature with elevation under particular circumstances. But the phenomenon evidently extends to greater heights, as is manifested by the frequent gradual increase of clouds from sunrise to 3 P.M., followed by their gradual disappearance until all have vanished, leaving the sky clear at and about sunset.

13. The connection between heat and evaporation is so close that the facts about to be mentioned in illustration of the diurnal periodicity connected with aqueous vapour, would in many instances serve equally well as illustrations of the above indicated diurnal periodicity in the change of rate of alteration of temperature with height above ground. This part of the subject is more complicated and less easy to comprehend owing in part to a paucity of suitable observations, and in part to some of the evidence apparently, but only apparently, pointing to a different conclusion from the remainder. However, as this question of the nature and causes of local differences will be considered when the variations from the general rule are discussed, it need not be further alluded to here. Suffice it to say that the facts confirming or pointing to the existence of a twenty-four hourly period in connection with aqueous vapour are convincing enough, when taken in conjunction with the evidence relative to the other elements, to warrant the belief that the daily periodicities of increase and decrease of humidity, increase and decrease of vapour tension, and of the vertical distribution of the dew point (or rather of the place of maximum humidity), are harmonisable and correlated with those presented by light and heat.

14. The subject of aqueous vapour as an element of climate presents several aspects, each of which should be kept distinct from the others. One is the rate at which the vapour is supplied or, in other words, alternations in the intensity of evaporation; another is the variation in the absolute amount of aqueous vapour in the air; and a third is the changing ratio which this absolute amount may bear to the quantity which would suffice for perfect saturation. It would occupy too long to treat all these, and therefore the distribution of the dew point and of maximum humidity will be selected on account of its affording the most striking exemplification of periodicity. But in order to connect this part of the evidence with that which has gone before, a few lines may be devoted to the data respecting the amount of aqueous vapour in the air. This amount depends upon the temperature, and its variations coincide in the main with those of temperature. The greatest quantity prevails during the hottest hours of the day (provided there is a source of supply of vapour within a moderate distance), while the smallest quantity is found during the coldest hours. The diurnal curve, then, of the amount of aqueous vapour usually agrees with that of temperature. It frequently happens that there is only a moderate source of supply, and then the quantity seems to diminish during the hotter hours. This is owing to the upward diffusion of the vapour and the consequent lessened amount of it in a given bulk of air.

15. The dew point and zone of maximum humidity occur in the coldest section of the vertical column of air. As a rule it is situated on the ground, especially on clear nights, and about sunrise it gradually ascends in the air until it has reached the zone where clouds are usually formed. As the time of maximum cloud occurs some hours after that of maximum dew, the probability is that this zone of maximum humidity gradually ascends from the time of sunrise until it reaches the cloud zone. Towards evening it again descends, reaching the ground when the dew forms, shortly before or shortly after sunset. If this view be correct then analogy would induce us to infer that from this zone of maximum humidity there is an increase of temperature downwards towards the ground and upwards as far, perhaps, as the normal position of the cloud zone. By way of illustration take the following observations made by Flammarion during balloon voyages from Paris, and other places in France. On June 10, 1867, he started from the ground at sunrise, at a time when the horizon was misty, and the fields covered with a fog which gave them the appearance of lakes. The humidity was 93 on the ground, and it increased to its maximum of 98

at the height of 492 feet. Above that it gradually diminished to 93 at 919 feet, 92 at 984 feet, 86 at 2461 feet and 61 at 4101 feet. On April 18, 1868, an ascent was made from Paris at 3.15 in the afternoon. The humidity on the ground was 73, and increased to 74 at 2546 feet, 75 at 2950 feet, 76 at 3412 feet, and 77 at 3773 feet. This was the maximum, and above this there was a gradual decline to about 30 at the height of 9843 feet. From the observations made during his numerous balloon trips, he concluded that the zone of maximum damp varies in elevation according to the time of the day, season of the year, and other circumstances; and that occasionally it occurs near the surface of the ground, especially at dawn. At Greenwich the result of several years of investigation was that (calling a cloudless sky 0, and one entirely overcast 10), the daily mean was 6·04 at 9.20 P.M., from which time there was a progressive increase as follows:—

11.20 P.M.	6·14
1.20 A.M.	6·41
3.20 „	6·76
5.20 „	6·84
7.20 „	6·89
9.20 „	7·10
11.20 „	7·14

From this time there was a gradual decrease: thus,

1.20 P.M.	7·11
3.20 „	7·00
5.20 „	6·61
7.20 „	6·23

At Rome the period of maximum cloudiness is from noon to 5 P.M. In the tropics during the rainy season the weather is so uniform that almost every day is characterised by the clearness of the sky at sunrise, the appearance of clouds at 10 A.M., their rapid increase till noon when the rain pours for a few hours, generally ceasing about 4, and then the clouds rapidly disperse, allowing the sun to set in unclouded glory. At Lucknow, as Bonavia observed in October, 1877, the clouds appeared day after day in the late morning hours and increased to a considerable extent before 3 P.M. After that hour they dispersed again, but did not quite disappear till about two hours after sunset. In Natal, as Dr. Mann informs us, it is usual for the sky in summer to get cloudy soon after noon, and to be overcast to a late hour at night, when the sky again clears. He also indicates that on the ground the condition of things is the reverse of that in the cloud zone, as the mean humidity at Maritzburg at 9 A.M. for a period of eight years was 71·2; at 3 P.M. it was 60·1, and at 9 P.M. it was 83·4. In the Sahara desert the minimum humidity near the ground occurs at about 2 P.M. Under certain conditions, more especially in localities near large lakes the order of things seems to be different, although a diurnal periodicity is still evident. Thus near lake Tanganyika, Burton states that sunrise is seldom clear, and that, if it is so, clouds gather in the forenoon with the rising wind, but disappear again between noon and 3 P.M., owing, in his opinion, to their being melted by the fervent heat of the sun; but as he also alludes to a marked fall in the wind, this circumstance may have some influence in the matter. Thick mists collect about sunset, and, as a rule, the skies at night are more or less clouded. At Geneva, again, where Plantamour has made observations for upwards of fifty years, the least amount of vapour occurs at sunrise, and the greatest about 2 P.M. during the winter months; whereas, during the summer, there are semi-diurnal periodicities. The morning minimum is shortly before sunrise and the maximum between 8 and 11; the afternoon minimum occurs between 2 and 4 P.M., and the subsequent maximum from 6 to 10 P.M. The precise hour varies according to the season. In the case of the clouds the winter daily maximum is at sunrise and the minimum at sunset. In the summer there is a double periodicity in the twenty-four hours. The morning maximum is shortly after sunrise, and the minimum from 9 to 11 A.M.; in the afternoon the maximum is at about 6 P.M., and the following minimum soon after midnight. Whatever may be the explanation of these curious phenomena, there is still apparent a daily march and an antithetical relationship between the increase and decrease of the humidity at the higher and lower levels.

16. There is a striking coincidence between the cloud changes at Geneva, and the two semi-diurnal barometric periods which are so conspicuously developed in the tropical day. Under the equator the maximum height of the mercury occurs at 9 o'clock, or a few minutes after, and the minimum with equal punctuality at 4 P.M. From this it rises, reaching its second maximum height soon after 10.30 P.M., and its second minimum at 4 A.M. This extreme regularity of barometric movement prevails for several degrees on either side of the equator. This double oscillation is due to the combination of two distinct diurnal periodicities. The one arises from the action of heat and cold in increasing and decreasing the amount of vapour in the air. It follows the same period as the temperature near the ground. Its maximum corresponds with the hottest hours, and causes a maximum of pressure, while its minimum corresponds to a minimum of pressure. On the other hand the air is so acted upon by this same alternation of heat and cold that its maximum of pressure occurs during the coldest hours when the air is densest, and its minimum at the warmest period. The one is the reverse of the other; and there is here a repetition of the antagonistic relationship observable in the diurnal curves of maximum humidity. The two actions give rise to a double barometric oscillation, in which the maxima occur when the two separate pressures are at their mean, and when, therefore, both co-operate in producing pressure, whereas the afternoon minimum barometric pressure is co-temporaneous with the highest vapour tension, while the morning minimum bears the same relation to the highest atmospheric pressure. In accordance with this, it is found that in proportion as

the absolute amount of aqueous vapour in the air diminishes, or in other words as the vapour tension decreases, so do the amplitudes of the barometric oscillation lessen. Thus there is a gradual diminution in the amplitude from the tropics towards the poles, and from the localities which have the greatest amount of aqueous vapour in the air towards those which have the least. The decrease in the amount of aqueous vapour may arise from two causes, as before mentioned, viz. a diminution of temperature and a diminished rate of supply owing to distance from the ocean and other large bodies of water. Hence the oscillations diminish from summer to winter, from the sea towards the interior of continents, and from the ground upwards. As with temperature and with aqueous vapour, an inverse relationship is noticeable between the fluctuations on the ground and at a definite, but considerable, height above it. From these statements it will be seen how closely interwoven are numerous meteorological subjects, and how a community of causes will account for the variations connected, not only with the period of day, but also with the latitude, the season, and the distance from as well as altitude above the sea. Other explanations have been offered as to the cause of the diurnal barometric oscillations; but the purpose in view here is not to discuss these explanations, or to point out the influences which produce the oscillations; but simply to adduce the best evidence available in favour of the barometric changes being due to a diurnal periodicity. The curve of daily barometric change is so totally different from that of temperature, that no relation seems possible; but a little attention shows that it may really conform with the daily thermic changes, directly in one way and indirectly in another. One or two local instances may represent many examples which could be cited to the same effect, did space permit. At Habana, in Cuba, the precise times of the maxima and minima vary with the seasons; the minima occur at 2.4 A.M., and at 3.4 P.M., and the maxima at 9 to 10 A.M., and at 10 P.M. Ellis says of the diurnal variation at Greenwich, that the morning minimum and the forenoon maximum are latest in summer; and that the changes in the time vary much in the same way as the times of sunrise and sunset vary; so that as the day lengthens, the interval between the forenoon maximum and afternoon minimum increases. The length of the night bears a similar relation to the interval between the evening maximum and morning minimum. At Oxford the mean daily time of the oscillations in May, deduced from observations extending over 16 years, are 3.55 for the first minimum, 7.55 for the first maximum, 4.25 for the second minimum, and 10.45 for the second maximum (Rundell). At Valentia the results for December 1877 were these:—

29·245 in	at 7 A.M.	Min.
29·263 „	„ 11 „	Max.
29·238 „	„ 3 P.M.	Min.
29·273 „	„ 10 „	Max.

At Leh there is a maximum at 9 A.M., and a minimum at about 5 P.M. There is but one diurnal oscillation here, a feature characteristic of places having a dry atmosphere. And as may be noticed the minimum occurs in the afternoon, the period when the atmospheric pressure by itself is presumably least.

17. If then the barometric changes silently declare that they are mainly under the governance of a diurnal period, the winds, which are admittedly dependent, in a great degree, upon the relative distribution of atmospheric pressure, should furnish examples to the same effect. Indeed, as the winds afford a clue to the general state of the atmospheric pressure over large areas, it frequently happens that casual notes on local winds are of material help in deducing conclusions respecting the diurnal barometric period. At maritime places in tropical regions there is a marked uniformity in the order of change of the winds, as has been noticed in other climatal elements. The day breeze commences soon after sunrise, increases in velocity as the heat increases, and ceases about four or five in the afternoon. The lull continues till about sunset, when a light breeze from the opposite quarter sets in, and continues through the night. This phenomenon has been found to exist at a great many sea-side places within and without the tropics. Winds present a second very remarkable periodicity. It has been pointed out by F. Chambers at Bombay. This periodicity presents two minima in the twenty-four hours, and consists of a rotation of the wind direction; which follows, or rather accompanies, the barometric changes. The southerly winds reach their maximum value at the time of the most rapid rise of the barometric curve, while the northerly prevail during the period of most rapid fall. The easterly winds predominate during the maximum, and the westerly during the minimum epochs in the atmospheric pressure. The double wind oscillation is as conspicuous at Calcutta as at Bombay. This oscillation, in conjunction with the alternate increase and decrease of pressure, demonstrates the existence of a daily flux and reflux of air over very wide areas. Rüppell observed something similar at Gondar, in Abyssinia; for, during his stay there, in the rainy season, the wind was N.E. in the morning, veering round to S.E. before 9 A.M., becoming S.W. by noon, and N.W. during the afternoon. At sunset the wind ceased. At Pola, in Illyria, there is a daily variation in the direction of the wind; it starts from a point E. of S. at 5 A.M., and gradually veers till it reaches its most westerly point about 6 P.M., from which time it shifts back to its starting point. The wind force also shows a diurnal periodicity. Thus at Pola the force is nearly double as strong from 11 A.M. to 6 P.M. as it is from 9 P.M. to 6 A.M. The elaborate observations by Osler at Birmingham give the following interesting results. In winter the force of the wind undulates about 220 from midnight until 8 A.M., rises to a maximum of 390 at 1 P.M., sinks to 350 at 7 P.M., and then declines till midnight. In the

spring it starts from 90 early in the morning, reaches the maximum of 300 at 1 P.M., sinks rapidly to 160 at 6 P.M., and then more slowly to 90. In the summer the rise is from 70 in the morning to 260 at 3 P.M.; and then a fall to the minimum. In the autumn the maximum of 260 is reached at 2 P.M. Many lakes have their morning and evening breezes, which sometimes blow with such astonishing regularity as almost to constitute a measure of time, as for instance on the Te Anau lake in New Zealand (McKerrow). At Geneva the daily fluctuations of the land and lake breezes are of a decided character. Plantamour has found that in December, when there is no perceptible difference in the temperature of the land and the lake, there is no prevalent lake breeze. In January the lake breeze sets in, and increases from month to month as the days lengthen and the temperature increases. The wind presents a periodicity in its other aspects, such as the time when violent storms commence. At St. Blaise, in Switzerland, the Peters family carefully noted the particulars respecting 260 storms of wind. Only sixteen of these began between 4 A.M. and noon, while 135 were initiated between noon and 8 P.M., and 70 between 8 P.M. and 4 A.M.

18. Inclination would induce us to give the confirmatory details afforded by the diurnal periodicities of rainfall, thunderstorms, distribution of the maximum and minimum intensity of atmospheric electricity, hailfall, ozone, and the chemical action of light. There is an abundance of material for this; but we refrain from further consideration of the subject, in order that we may avoid exhausting the patience of the reader.

19. The conclusions to be drawn from the foregoing facts are: that each element of climate is liable to a regular daily change, primarily dependent upon the earth's rotation and the consequent exposure to the sun, the amount and degree of which varies with every locality; that in some the increment and decrement constituting the period is regulated by the light or heat, so that the maximum is attained soon after the hottest hours; that in others the period is regulated by the action of heat converting water into vapour, so that the maximum is produced during the coldest hour of the day; that the hour of greatest heat or of greatest cold differs according to the height above the ground, causing a vertical oscillation of the period between the ground and the cloud zone; and, lastly, that when heat alone and heat acting by the agency of aqueous vapour, co-operate, the maximum effect produced by each separately is so counteracted by the other, that the combined result of their co-operation is to produce a minimum effect, while the maximum occurs when each is at its mean and both act together; the result of which is an apparent double maximum in the course of the day. The maze of changes may seem very confused; but, in reality, however complicated the arrangements are, all is in perfect order. Thus having completed the round, the mind recurs to the subject which occupied our thoughts in the opening paragraphs of this essay.

A. R.

GENERAL REMARKS.

In these notes the term general has an indefinite as well as a definite meaning. It includes, as it should do, titles and facts which relate to climate generally, such as "On the Uniformity of Insular Climates;" and, in the case of districts, those which apply generally to them, such as "The Meteorology of Holland." There are many titles which are expressed generally, but which manifestly apply to some particular district; as, for instance, "Meteorological Abstract for the Years 1794–1799." As the special district is not stated, such papers, etc., are entered here; when they have been read the titles are repeated under the name of the districts to which they relate. Particulars respecting the application of telegraphy to meteorological purposes, broad references to cycles, propositions for organised methods of research, notices of the healthiness or unhealthiness of places, are considered to be general. In addition to these there are items which cannot be regarded as general, but which, owing to their vagueness, cannot be definitely placed; so that the only position for them is under general. One instance of this is Fothergill's paper in this number (1805, 2), which may seem to be quite out of place. The only reason for putting it here is the "etc." When this paper has been read, the facts represented by "etc." will be entered in their proper places; but in the meanwhile it is considered to be indefinitely general. Again, certain papers and facts are entered under general, about which there is great uncertainty as to whether they are meteorological at all, as for instance, blood rain, black rain, red snow, showers of frogs, and other strange objects, and similar subjects. Papers of this kind often contain some meteorological data. Remarks on storms of the character of which no specific mention is made are grouped as general. The atmosphere is considered to be distinct from climate; consequently facts relating to its physical and chemical qualities, which do not concern climate, are not to be found here, but under the section devoted to atmosphere. The papers and paragraphs are numbered so as to facilitate reference. As a matter of convenience the volumes of a serial are entered under the year of publication, but when the date is lumped, and the volumes have not been examined for the purpose of ascertaining the year of issue of each volume, the serial is assigned to the general section subordinate to Bibliography. Descriptions of instruments are not considered to be meteorological, except when the statements made bear upon recorded readings. When the volume has a date extending over one year, the title is placed under the latest year mentioned.

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ESSAY II.

ON THE CONNECTION BETWEEN SOLAR PHENOMENA AND CLIMATIC CYCLES.

BY PROF. E. DOUGLAS ARCHIBALD, M.A., F.M.S.

PART I.

"The sun is at once the motor of all things, the agent of light, and the principle of thought."—*Vedas.*

1. THE sun's heat is so manifestly the source of all climates, that changes in the amount of heat radiated from its surface are now regarded as the main cause of the changes in terrestrial weather. Besides the semi-annual and seasonal changes caused by its varying distance from the earth, and relative position with respect to the plane of the equator, it has been suspected that changes occur from time to time in the *body* of the sun itself, which produce variations in the amount of heat radiated from its surface and thereby affect terrestrial weather. The sun-spots, which are the most striking of the indications of solar disturbance were discovered by the Chinese [1] in the beginning of the present century, and are now proved by the extensive labours of Schwabe and Wolf, supplemented by the more careful delineations of Messrs. De La Rue, Stewart, and Loewy, to undergo a complete cycle of variation every 11·11 years. [2] One of the first results of the approximate determination of the foregoing cycle was the discovery by Messrs. Sabine and Wolf of the coincidence of this period with those of the maximum and minimum intensity of terrestrial magnetism and displays of the Aurora Polaris. This coincidence being too marked to be merely fortuitous, it was hence conjectured that, since the majority of the changes in magnetic variation and auroral frequency are probably either directly or indirectly related to corresponding changes in terrestrial meteorological currents, some connection might be found to exist between the secular variations in sun-spot frequency and area, and those in the different elements of terrestrial meteorology. The universal principle upon which this conjecture was founded, is that which is emphatically laid down by Herschel in his "Meteorology," viz., "that all periodicity in the action of a cause propagates

[1] *Vide* 'Monthly Notices of the Astronomical Society,' vol. xxxiii. p. 370.

[2] According to De La Rue this period is 11·07 years. The period of increase from minimum to maximum comprising 3·52 years, and of decrease from maximum to minimum 7·55 years. Lamont makes out the length of the period to be 10·43 years, but this does not accord well with the latest observations.

itself into *every*, even the *remotest* effect of that cause through whatever chain of intermediate arrangements the action is carried out."[1] There is, then, some ground for believing a connection to exist between the eleven-year period of solar maculation, and that of some kind of emission dependent upon the particular meteorological or thermal conditions of the sun's surface, with its accompanying train of terrestrial, meteorological, and magnetical effects. It will be noticed that the magnetical disturbances are here assumed for the most part to follow and be dependent upon the meteorological disturbances, and lest such an assumption be thought to be without foundation, it may be stated that it was prominently upheld by so distinguished a physicist as Prof. Balfour Stewart in his presidential address before the British Association in 1875.

2. From the very earliest times we find a popular tendency to expect the weather to recur in cycles of about ten or twelve years. Mr. Sayce, in an article in 'Nature,' entitled "The Astronomy of the Babylonians,"[2] remarks that they used cycles of twelve years, during which they expected the same weather to recur; and if it is remembered that their years only contained 360 days, it will be found that twelve of their years would correspond to about 11·8 of ours, and therefore nearly coincide with the eleven-year cycle of sun-spots. More recently in 1835, and before the sun-spot cycle was completely established, it was known that frightful droughts in Australia occurred in cycles of from 9 to 10 years,[3] while in Ceylon a weather cycle of 11 years appears to be universally recognised, forming part of a grand cycle of 33 years, and oscillating in length between 10 and 12 years, and perhaps in this very element of uncertainty, corresponding all the more correctly with the spot cycle and its unequal periods of variation.[4]

3. Before, however, entering upon the question of weather-cycles, or alluding to the numerous attempts that have been made to exhibit a connection between solar and terrestrial meteorology, it may be as well to examine briefly the nature, peculiarities, and supposed origin of sun-spots as revealed to us by the telescope and spectroscope, in order to see how far we are justified in assuming, *a priori*, that they are capable of exerting any appreciable effect upon terrestrial temperature and weather.

The only way in which we will at present suppose them capable of affecting terrestrial climate, is by their presence tending to increase or diminish solar radiation, and to this test all results of our enquiry must be applied.

[1] Herschel's 'Meteorology,' p. 137. Stanley Jevons calls this the principle of "Forced Vibrations." The 'Principles of Science,' p. 451.

[2] 'Nature,' vol. xii. No. 310.

[3] 'Westminster Review,' July, 1835. No. 45.

[4] Dr. Wolf who has been collecting information regarding sun-spots for the last 40 years, has recently found the average divergence of the sun-spot period from the mean period of 11·11 years to amount to as much as ± 2·03 years; the time which elapses between two consecutive maxima being sometimes as long as 15 or 16 years, while at other times it amounts to only 7 years.

4. First as regards observations with the telescope. From the researches of Messrs. De la Rue, Stewart, and Loewy, as to the nature and position of the spots in the sun's photosphere, by the help of the telescope and photoheliographs, we learn (1) "that the umbra of a spot is nearer to the sun's centre than the penumbra;" (2) "that solar faculæ and probably also the whole photosphere, consist of solid or liquid bodies of greater or less magnitude, either slowly sinking or suspended in equilibrium in a gaseous medium;" (3) "that a spot including both umbra and penumbra is a phenomenon which takes place beneath the level of the sun's photosphere."[1] It is also found that the luminous flakes called "Nasmyth's willow leaves" (or "Huggins's granulations") of which the photosphere, and the faculæ (which appear to be denser and more elevated portions of the photosphere in the vicinity of the spots) are composed, are scarcer and more rarified in the neighbourhood of the spots than in the other portions of the photosphere. These willow leaves were somewhat fancifully supposed by Sir John Herschel to be organisms of some peculiar and amazing kind, but, whatever they might be, he thought, they were evidently the *immediate sources of the solar light and heat.*

5. Telescopic observation further shows, that the formation of a spot is usually preceded and accompanied by the appearance of faculæ, from which we may conclude, that though there is a palpable decrease in the amount of light emitted by a spot, compared with that emitted by the photosphere itself, it is partially, if not entirely made up for by that emitted from the facula, or region of increased brightness by which it is surrounded. Amongst other telescopic observations during the present century, Mr. Carrington observed:—

(1) "A motion of the spots towards the equator;"
(2) "That this motion is in a direction contrary to that of the sun's rotation;"
(3) "That spots appear to get divided by a certain whirling motion of their parts;"
(4) "That new spots more readily appear where others have previously disappeared;"
(5) "That there is a periodicity in the frequency of sun-spots, the last maxima being 1828, 1837, 1848, 1860, and 1872."

M. Chacornac likewise noted the wonderful rapidity with which small spots are precipitated into large ones, amounting occasionally to as much as 599½ miles per second.

6. Messrs. De La Rue, Stewart, and Loewy, among the numerous results of their organised researches at the Kew Observatory, not long ago announced a discovery to the effect that during periods of great disturbance, there is a tendency in the spots to change from the northern to the southern hemisphere, the period of such change being about twenty-five days, and that outbreaks occur in pairs at the ends of the same solar diameter, after

[1] Proctor, 'The Sun,' p. 217.

an interval of about thirteen days. Prof. Langley, of Pittsburgh, from a careful study of the sun's surface, considered the spots to be places where we see the general structure of the photosphere in sections, owing to the filaments composing it being here inclined. He also recognised the presence of both horizontal and vertical cyclones within the spots.

7. As has already been mentioned, it was observed by Mr. Carrington that spots nearer the solar equator move more rapidly in the direction of rotation than those more remote. He was thus led to assign to them a proper motion of their own.[1] This motion has to be considered in measuring the sun's period of rotation by observations of their successive appearances and occultations. Herr Spörer arrived independently at the same conclusion, and deduced the mean period of rotation from observations of spots near the solar equator to be 25·3 days. The spots are however found to be mainly confined to a zone extending some 30° each side of the equator, *very few* being observed in higher latitudes, and *fewer* at the equator itself, than in the adjacent zones on each side of it.

8. The size of the spots is not unfrequently very great. Capt. Davis made a drawing of one in 1839 which had a double nucleus, and whose superficies, including the penumbra, was about 25,000,000,000 square miles. It may help us in endeavouring to form some idea of the immense size of these cavities to learn that the earth, if projected into the interior of a spot like this, would appear no larger than a fragment of rock rolled into the crater of a volcano!

9. The faculæ which generally precede and accompany the spots, from recent investigations by Messrs. Balfour Stewart, and De La Rue, are found to be disposed more frequently to the left of the spots than to the right, that is *behind* as regards the direction of rotation. In fact, out of 1137 spots photographed at Kew, Mr. De La Rue found 584 which showed faculæ to the left, 508 had them disposed symmetrically on either side, and only 45 exhibited them on the right—that is, in front, as regards the direction of the rotation.

10. Quite recently, M. Janssen, of the Paris Observatory, has succeeded in taking some very fine photograms of the sun, from which it appears that, in addition to the granulations noticed by Huggins and others, the entire photosphere exhibits a reticulated structure, being made up of a series of figures "which have in general rounded contours, but are often almost rectilinear, thus forming polygons." "The dimensions of these figures are very variable; some are even 1′ in diameter (over 25,000 miles)." "Between these figures the grains are sharply defined, but in their interior they are almost effaced, and run together as if by some force." M. Janssen also observes with respect to the granulations, that the most luminous particles, or those to which the solar light is chiefly due, occupy only a small fraction of the solar surface.

11. One of the most remarkable phenomena connected with the telescopic

[1] Observations of spots from Nov. 1853 to March 1861 at Redhill, by R. C. Carrington.

study of the spots was the discovery by Mr. Carrington of the tendency of the limiting parallels between which the spots were found, to contract previously to the minimum, and soon after this epoch the commencement of two fresh belts of spots in *high latitudes* north and south, which have in subsequent years shown a tendency to coalesce, and ultimately to contract as before. This phenomenon was what mainly suggested to Sir J. Herschel, the meteoric ring theory of the origin of sun-spots, in which these bodies forming a cam-like ring were supposed to impinge upon, and perforate the photosphere, its period of revolution corresponding with that between two similar phases of the spots, and the sudden appearance of the spots in high latitudes accounted for by the above peculiar distribution of the meteors in the ring.

12. Though the preceding discovery is as remarkable as any that have been obtained by a long and patient study of the changes that occur on the sun's surface, and will probably be of material assistance in helping to unravel the secret of the origin of the spots, it has been recently well-nigh eclipsed by the discoveries of the Kew observers with reference to the apparently complete dependence of the apparition and movements of the sun-spots upon the relative positions of the nearer planets, Mercury and Venus. Prof. Balfour Stewart thus sums up the facts hitherto ascertained: First, when either Venus or Mercury is between or nearly between our earth and the centre of the sun, as the sun-spots are carried round by rotation nearer to the planet, they become less, and as they are carried away from the planet, they became greater; secondly, when Venus or Mercury is at the extreme right of the sun, the spots diminish in size all the way across; thirdly, when Venus or Mercury is on the other side of the sun, exactly opposite the earth, the spots have their maximum in the centre; and finally, if Venus or Mercury be at the extreme left, the spots augment in size all the way across; in short they are always least in the immediate neighbourhood of Venus or Mercury and greatest when that portion of the sun to which they are attached is carried by rotation to the position farthest from the influencing planet.[1]

More recently still, Prof. Stewart has found periods of sun-spot activity of about twenty-four days' duration, so definitely marked and so regular, that he can tell their period to within ten minutes. These periods both he and Dr. Buys Ballot attribute to the influence of intra-mercurial planets. They are also found by Prof. Stewart to exist almost as markedly in the diurnal temperature ranges at Toronto, which is the only place he has at present examined. The relation between the two phenomena is of such a character that an increase of sun-spots corresponds to an increase of diurnal temperature range.

So little, however, is known at present concerning the particular agency by which the planets can be supposed to affect the production and subse-

[1] It may be remarked, if only as a mere coincidence, that the recent prolonged period of minimum sun-spot, 1875-9, was remarkable as an epoch of conjunction of several of the larger planets.

quent motions and appearance of a sun-spot that we are forced to abandon the question for the present until it is somewhat more simplified by further discoveries. Although from the preceding brief résumé of the results of telescopic observation of the spots, it is evident that a careful telescopic study of the sun's surface is likely to be attended with valuable additions to our existing knowledge of the conditions which regulate the changes in the appearance and distribution of the spots, it is plain that with regard to the question whether their presence or absence is likely to be attended with an increase or decrease in solar radiation, or solar temperature (which need not necessarily co-exist in the same degree), no positive evidence seems likely to be obtained. From the recent telescopic observations of the Kew observers, however (according to Mr. J. N. Lockyer), evidence is not wanting to show that in years of minimum sun-spot there is a less amount of cold absorbing atmosphere above the photosphere, and consequently a smaller tendency to the downrush of cold matter in large quantity.[1] In years of maximum sun-spot, on the contrary, the absorbing envelope is denser, and therefore assuming that the internal heat is not increased to an extent sufficient to counterbalance the effect of the increased absorption, both general throughout the photosphere, and general and selective in the region of the spots, it may be conjectured that in such years the solar radiation ought to be less powerful than it is in years when few spots are visible; an hypothesis which, as will be seen hereafter, is susceptible of a large amount of direct as well as indirect proof founded upon the results of comparing observations of solar radiation and terrestrial air temperatures and other elements for different years of the spot cycle.

13. It must be borne in mind, however, that the preceding hypothesis presupposes the existence of a downrush of cold absorbing atmosphere in the region of the spots, the existence of which, though inferred from the telescopic observations of Lockyer, has only been finally placed beyond the possibility of doubt through the evidence afforded by the use of the spectroscope. On this, as well as on many other points, the evidence given by the telescope alone with respect to the nature, peculiarities, and possible origin of sun-spots, is now so amply supplemented by that derived from spectroscopic analysis, that theories formed solely from observations with the former are of little real value unless they are compatible with, and conclusively borne out by, the results obtained through the assistance of the latter. The preceding theory of a downrush in a spot, and the rival theory of an uprush, the former being that held by the Kew observers, and the latter that of M. Faye, have been subjected to the rigorous method of analysis afforded by the spectroscope. The result has been to confirm the former theory in the most decided manner. M. Faye has in consequence renounced his theory, and has adopted one in which cyclonic action is considered to be the prime producer of the spots. Mr. Lockyer further remarks: "A suggestion has also been made by the Kew observers

[1] 'Solar Physics,' by J. N. Lockyer, F.R.S., p. 481.

to account for the change in the density of the absorbing layer [noticed above], which promises to be one of great value, in assisting towards the discovery of the causes of the periodicity of the occurrence of the spots. It is this, that assuming the photosphere to be the plane of condensation of gaseous matter, the plane may be found to be subject to periodical elevations and depressions, and that at the epoch of minimum sun-spot frequency the plane might be uplifted very high in the solar atmosphere, so that there was comparatively little cold absorbing atmosphere above it, and therefore great difficulty in forming a spot."[1] This idea has since received partial confirmation at the hands of Mr. Lockyer and Professor Tacchini, but can scarcely be regarded as definitely settled at present. The Kew observers, whose theory of a downrush is thus strongly supported by spectroscopic evidence, apply it to explain the proper motion of the spots noticed by Carrington in the following terms. "May not the falling behind of the faculæ be the physical action of the spots noticed by Carrington, so that while the current passing upwards falls behind, carrying the luminous matter with it, the current coming down moves forward, carrying the spot with it, and may not this current coming from a colder region account for the deficient luminosity which characterises a spot?" This idea is strongly supported by collateral evidence, and fully explains the appearance of vertical cyclones as observed in the interior of the spot.

Before concluding this brief notice of the results of telescopic enquiry, it may be finally remarked, that in a group of spots which are gradually breaking up, the one which is furthest advanced in the direction of rotation disappears last. This is a point which certainly deserves careful notice, especially if in dealing with the question of their origin, we can ever hope to build up any satisfactory theory with regard to sun-spots.

14. On bringing the spectroscope to bear upon the spots—to use the words of Professor Tait of Edinburgh,—"the normal solar spectrum is seen only with this difference, that the absorption lines are *thicker* and *darker* than from sun-light as a whole; so that it appears that there is associated with the sun-spot something which produces *an excess of absorption*." This widening of the spectral lines, however, may be due to at least two distinct causes. If the increase takes place equally on both sides, as Lockyer and Frankland have shown, it indicates an increase in the pressure and density of the layers composing the spot; if, on the contrary, the line undergoes an unequal expansion, sometimes on one side and sometimes on the other, it is most probably due to the presence of gaseous tornadoes within the spot, in which portions of gas are descending and ascending with tremendous velocity.[2]

15. With regard to the explanation of the abnormal appearances presented by the spectrum of a sun-spot, Schellen says: "From the results of the spectrum observations of Secchi, Lockyer, and Young, it may be re-

[1] 'Solar Physics,' by Lockyer, p. 481.

[2] Lockyer says that the velocity is about 38 miles a second.

garded as certain that the phenomena of increase in the width and intensity of the Fraunhofer lines are produced by the *increased absorptive power exercised by the substances of which the spot is formed.*"[1]

16. On the whole therefore the evidence given by the spectroscope concerning the solar spots, confirms the idea that they are due to the existence of masses of relatively cool vapours at a lower level, and therefore relatively more compressed than the vapours elsewhere existing in the solar atmosphere. At the same time it throws little additional light upon their extraordinary movements over the sun's surface as revealed to us by the telescopic researches of Carrington and others.

17. These movements are in many ways so similar to those of terrestrial cyclones that the spots have in consequence frequently been called solar cyclones. Sir John Herschel, and more recently Mr. Herbert Spencer, have formed theories to account for them on this supposition, that they are really cyclones in the solar atmosphere, the latter applying rules to them very similar to those which hold for their terrestrial analogues.

18. It would be unnecessary if not impossible for us to attempt to enter into a detailed account of the various theories that have been propounded from time to time by distinguished physicists, regarding the nature of sun-spots. Kirchoff, De La Rue, Stewart, Loewy, Carrington, Sir J. Herschel, Lockyer, Young, Respighi, Secchi, Zöllner, Faye, Huggins, Dawes, Spörer, Lalande, Chacornac, Rayet, Tacchini, Weber, Weisse, and others, have by their laborious investigations; with the help of both the telescope and spectroscope, contributed immensely towards our knowledge of these phenomena; but though much has been elucidated with regard to their nature and peculiarities, much is still involved in uncertainty.

19. Lockyer considers them to be deep recesses in the surface of the solar body, filled with concentrated masses of those substances (iron, calcium, barium, magnesium, sodium, and hydrogen), the lines of which undergo an increase of breadth and intensity in the spectrum, and over which floats the lighter hydrogen gas.[2] Zöllner appears to hold somewhat similar views, and regards them as the sequelæ of hydrogen eruptions consisting of a kind of scoria, which sinks by its own weight a certain depth into the photosphere or outer portion of the sun, and partially intercepts the light from the lower stratum of the photosphere; therefore presenting to us an appearance of a dark mass projected upon the disk of the sun, in the same way as the exceedingly intense light of the oxy-hydrogen lime.

[1] Schellen, 'Spectrum Analysis,' p. 290.

[2] Mr. Lockyer has recently (Oct. 26, 1880) communicated a brief note to the Royal Society, (Proc. Roy. Soc. vol. xxxi. No. 207) on the spectra of some iron lines in a sun-spot observed on August 31, 1880, from which it appears that "when the iron line at 5207·6 (wave-length) was doubly contorted, indicating an ascending and descending velocity of about 15 miles a second, the two adjacent lines at λ 5203·7 and 5201·6 visible in the same field of view were unaffected." This affords strong confirmation of the opinion put forward by Mr. Lockyer in December 1878, that iron, like other so-called elements, is in reality a compound, which by the enormous heat of the sun is resolved into its elementary molecular groupings, of which he thinks there are no less than three.

light appears black when seen against the sun. M. Gautier of Geneva holds precisely similar views to those of Professor Zöllner, and says that they appear to him to be the only ones which neither contradict the ordinary laws of physics nor well-known facts. Secchi also appears to hold almost identical views with Zöllner as far as he ventures to go. Thus in 'Le Soleil,' 2nd part, p. 184, where he sums up his idea of the nature of sun-spots, he says: "La conviction à laquelle nous sommes arrivés après celle longue série d'études est celle-ci: la tache est formée par la matière même que l'éruption projette sur le disque solaire; la région obscure est due à l'absorption exercée par les vapeurs qui sont sorties du sein du corps solaire et sont interposées entre l'observateur et la photosphère." On the whole it appears somewhat difficult to account for the multifarious peculiarities in the nature, formation, and disappearance of sun-spots by adopting any one single theory regarding their nature. Nevertheless from the results of the most recent investigations, both telescopic and spectroscopic, we may safely entertain the following general conceptions with respect to their probable nature and influence.

(1.) That they are phenomena of *condensation* rather than of *expansion*, and therefore due more to the action of *external* than *internal* forces.

(2.) That they exercise a general absorption, as indicated by a general thickening of all the Fraunhofer lines in the spectrum, plus a selective absorption indicated by the abnormal thickening of the dark lines of those substances—barium, magnesium, sodium, etc.—which are consequently supposed to occupy their deepest recesses.

(3.) That though they do not by any means indicate regions of total darkness].[1] they still exhibit a marked deficiency in the number of Nasmyth willow-leaves and luminous flakes, of which the photosphere appears to be mainly composed.

(4.) That they exhibit strong indications of cyclonic indraught and outrush, and are associated with periods of more than ordinary solar disturbance, including a greater number of jets and prominences in the chromosphere.

(5.) That though their maxima phases appear to be associated with a greater number of prominences in the chromosphere, the district where the latter occur most frequently, lies between N. and N.W., at about 45° north solar latitude, a region where solar spots are rarely seen. The two phenomena have consequently been hitherto considered quite distinct. Not long ago, however, Secchi came to the conclusion that the spots and faculæ were both secondary phenomena, similar to one another in their mode of formation, both being the cooled gaseous products of solar eruptions sinking back upon the photosphere, the spots being the sequelæ of *metallic*, and the faculæ of *hydrogen* eruptions. The spots being composed of heavy metallic vapours, generally occupy cavities of displaced

[1] The light emitted by the blackest umbra has been found by Professor Langley to be equal to at least 5000 times that of the full moon (*Vide* 'Nature,' vol. xii. No. 307).

photospheric matter. The faculæ, on the other hand, being composed of the lighter hydrogen gas, exist above the general level of the photosphere, their abnormal brightness being due to the greater transparency of the hydrogen, of which they are composed, for the photospheric rays, than that of the usual layer of metallic absorbing vapour which it has displaced. The greater obscurity of the spots is accounted for as usual, by the greater absorbing influence of the cooled metallic vapours composing them. Secchi differs from most other physicists in attributing the formation of the spots solely to the action of the gases composing the *metallic* protuberances. According to him, therefore, we must consider the period of maximum sun-spot, to be one in which a *larger proportion of absorbing metallic vapour exists above the photosphere than at the period of minimum sun-spot.* This accords very well with the fact already mentioned, as noticed by Lockyer, and to which his attention was first attracted, by observing that the spectral absorption lines were generally thicker throughout the solar disk at the former than at the latter period. Further, in looking for the origin of the sun-spots, we must remember that according to this view they are merely *secondary* phenomena, and that what must really be sought out is the prime cause of, and conditions of variation in, the metallic protuberances themselves.

20. If we leave the path of results founded upon direct observation, and endeavour to penetrate far enough into the domain of conjecture to furnish ourselves with an answer to the question—What is the influence that gives rise to the sun-spots, or, rather, the prominences of which they appear to be the after-effects, and regulates the sub-annual and secular variations in both phenomena ?—we shall find ourselves involved in an exceedingly perplexing labyrinth of mystery and confusion. Various and conflicting are the theories which have been propounded from time to time to account for the appearance of sun-spots. Several of them, however, owing to their being inconsistent with facts established by recent researches in solar physics, have been necessarily abandoned. One theory, based on their well-ascertained eleven-year cycle of variation, is worthy of notice, and endeavours to account for them by the influence of planetary attraction. Messrs. De La Rue, Stewart, and Loewy sometime back endeavoured to show that this period was in some way connected with, and dependent upon, the period of Jupiter's revolution in his orbit. The sun-spot cycle, however, according to Wolf, is fixed at 11·11 years, a period differing too much from that of Jupiter's revolution to accord with this hypothesis; for, as Proctor says, "We have not to go far back to find periods of spot maxima corresponding with Jupiter's position—(1) at aphelion; (2) at perihelion; (3) at his mean distance." [1] They have, however, as has been already briefly remarked, succeeded in discovering traces of the influence of both Venus and Mercury upon the behaviour of sun-spots. This influence appears to be of such a nature that the sun-spots attain their maximum size when carried

[1] 'Science Byways,' p. 125.

into positions as far as possible remote from the influencing planet. They also notice that when one of these planets passes across the plane of the sun's equator, it drags as it were the spots into the equatorial region of the disk; they spread towards the poles on the contrary when the planet passes away from the equatorial plane.[1] The theory, nevertheless, of their being entirely due to planetary influence, gives no satisfactory explanation of several peculiar phenomena in connection with the appearance of sun-spots, amongst others the apparent downrush and condensation that takes place in their interiors, and the appearance of greater brightness in the inner, compared to the outer edge of the penumbra. Kirchoff's theory of their being dense agglomerations of vapours *superimposed* on the photosphere, which for some time obtained numerous adherents, is now finally discarded, chiefly in consequence of the fact which recent spectroscopic investigations have brought to light, viz. that instead of the photosphere being surrounded by a cool atmosphere (assumed to exist in order to account for the degree of condensation requisite for the production of clouds), it is surrounded by an intensely hot stratum of gas, which forms what is generally known as the Sierra chromosphere.[2]

21. It may be remarked that though a dense agglomeration of vapours relatively cool enough to be visible as a dark mass, could hardly quietly float about in the chromosphere, a sudden irruption of cooled vapours from regions beyond the chromosphere, such as those shot out by the prominences, might temporarily exist as a dark spot, not only in the chromosphere, but below the level of the photosphere. Indeed, the very fact that spots form cavities in the photosphere, would seem to show that the cooled gases are projected (probably fall back) upon it with sufficient velocity to maintain their low temperature, unaffected for a time at least by their surroundings. Mr. Herbert Spencer's theory, a full account of which is given in Louis Figuier's 'Day after Death,' avoids the error into which Kirchoff is found to have fallen, in assuming the spots to be clouds suspended above the photosphere, and supposes them to be clouds of metallic vapour formed by the rarefaction, and consequently refrigeration, which takes place in the interior of a solar cyclone. He likewise accounts for the peculiar aspect of the penumbra already alluded to, by supposing that for some distance round a cyclone there will be a drawing in of the superficial gases towards the vortex. "All the luminous spaces of more transparent clouds, forming the adjacent photosphere, will be changed in shape by these centripetal currents, they will be greatly elongated, and those peculiar aspects which the penumbra present will be so produced." This theory doubtless seems to be satisfactory in so far as it avoids placing the clouds when it has been shown they could not possibly exist; but at the same time it attempts no explanation of the cause of the solar cyclones upon the assumption of whose existence it is alone founded.

[1] 'Researches in Solar Physics,' by De La Rue, Stewart, and Loewy.

[2] *Vide* Schellen, 'Spectrum Analysis,' p. 415.

22. A comparatively new theory, and one which disposes of many difficulties connected with the explanation of the violent eruptive forces displayed by the jets and prominences in the Sierra, has been propounded by Professor Young, of Dartmouth College, Hanover, U.S., in which he considers the Sun to be an immense gaseous bubble, the external envelope of which is formed of metallic rain falling from the photosphere of luminous clouds which floats above it. This rain, on approaching the Sun's strongly heated interior, becomes revaporised, thus forming a nearly continuous envelope, through which the eruptions which form the jets and prominences take place. Proctor says: "In other words the Sun according to this view is a gigantic bubble, whose walls are gradually thickening, and its diameter diminishing, at a rate determined by its loss of heat. It differs, however, from ordinary bubbles in the fact that its skin is constantly penetrated by jets and blasts from within." [1]

According to this theory the spots are supposed to be places where the photospheric clouds are thrust aside, by the cyclonic downrush of matter from without, and the metallic rain thus rendered visible through the opening. The luminous clouds thrust aside by this assumed downrush, being heaped closer together, would naturally shine with greater intensity, and consequently appear as faculæ lining the regions of the spots. This theory likewise accounts for the peculiarity previously alluded to in the penumbra, viz., that it is brighter at its inner than at its outer edge; that is to say, if, according to Proctor, we assume that the lower limit of the showers falling all round a spot lie closer than the upper ones (which appears likely owing to the indraught caused by the whirling gases), we should expect to find, as we actually do in reality, that the lines of rain will come closer together, and therefore appear brighter as they converge towards the centre of a spot. Proctor appears to consider this coincidence so important as "to throw serious doubts upon all the other theories which have hitherto been propounded in explanation of spot phenomena." [2]

23. M. Faye formerly held a theory somewhat similar to that of Professor Young, and agreed with him in considering the photosphere to be the effect of partial condensations, but attributed the spots to vertical ascending and descending currents within the photosphere, spots being produced where the *former* predominate, and the luminous matter of the photosphere is temporarily dissipated, while the retardation of the different zones of the photosphere, noticed by Carrington and Laugier, was accounted for by the rupture of equilibrium produced by the currents.[2] Professor Young, however, in dealing with the sun's spots, evidently assumes according to his theory that the primary movement commences from *without* in the form of a *downrush*.

24. The question, then, whether the primary movement commenced from within, or without, was for some time the chief point of difference between

[1] 'Science Byways,' by Proctor, p. 123.

[2] 'Sur la Constitution physique de Soleil,' par M. Faye. Comptes Rendus, Paris.

the two rival thories. As I have already had occasion to remark, however, M. Faye has been forced to renounce his idea of the primary movement commencing from within, owing to the incompatibility of this condition with the evidence afforded by spectroscopic analysis. Professor Young's theory on the other hand, does not by any means preclude the possibility of the co-existence of an outrush of gas from the spot, but rather makes this phenomenon a necessary consequence of the downrush. Altogether it appears to coincide very well with Secchi's and Zöllner's notion that the spots are the sequelæ of eruptions of gas from the jets and prominences in the Sierra, the condensed gas or scoria sinking into the photosphere by its own gravity.

25. There is, however, an addition which may be made to Professor Young's theory, effecting a slight modification in it without affecting its intrinsic worth, from which the peculiarly limited area occupied by the spots on the solar disk, the constancy of the sun's light and heat, and the phenomenon of downrush have been hitherto thought to flow as necessary consequences. I allude to what is generally known as the meteoric theory of solar heat, a theory which was started a few years ago by Mayer, Waterston, and Sir W. Thomson, in which the sun-spots are supposed to be perforations in the photosphere caused, or at any rate aided in their production, by a periodic rain of meteors, or the straggling meteoric masses, in the train of some yet undetected comet travelling in an orbit of eleven years round the sun.

26. If we accept Schiaparelli's theory of the common origin of shooting stars and comets, and combine it with Professor Tait's notion of the constitution of comets, which he considers to be "swarms of stones or meteors from which stragglers are continually falling into the sun, owing to their tangential velocity being checked by the collisions that are constantly taking place amongst them,"[1] we shall have little difficulty in understanding how even comets, ordinarily known as such, might during their perihelion passage assist the body or bodies of undetected meteors already alluded to in producing the solar spots. In proof of a general connection between sun-spots and comets, the zones which the former occupy on the solar photosphere are found to correspond in general with the curves in which tangent planes to the cone of cometary orbits, if produced, would intersect the sun. It may however be objected to this theory, that no meteoric or cometary system can pour a steady hail of meteors on the sun, for he is their ruling centre, and therefore under ordinary circumstances their orbits should pass round him without intersecting his substance. It must be remembered nevertheless, as Proctor says, "that they are infinitely more crowded in the neighbourhood of the sun than at a distance from him, and therefore at perihelion an indefinite number of meteoric orbits must intersect, and collisions be continually taking place between different members of countless systems."[2]

[1] Tait's 'Recent Advances in Physical Science.'

[2] 'Other Worlds than Ours.' Proctor.

In the sun's immediate vicinity, therefore, we may expect to find the conditions fulfilled for a constant rain of meteors (probably increasing and diminishing periodically according to the density of the streams) upon particular zones of the sun's surface.

The preceding hypothesis has since been abandoned by one of its earliest promoters (Sir W. Thomson), as being incompatible with a well-ascertained fact, the impossibility of the existence of a resisting medium in the immediate neighbourhood of the sun.

It has, however, been remarked that such a medium is not essential to the theory, since the same cause which accelerates the motion of Encke's comet is capable in the long run of precipitating meteoric streams on the sun's surface.[1]

It is also in accordance with the now universally held theory of the origin of the sun and other members of the solar system, that they have been formed by the continual aggregation of meteoric matter. Further, it has been recently shown that the majority of the substances composing meteors are found by their spectra to exist in the sun. Prof. Maskelyne, for example, has proved that thirteen out of the twenty-four elements which have been found in fallen meteorites, exist in one or other of the solar envelopes, while the rest, as Mitscherlich, Ängstrom, Wüllner, Secchi, and Zöllner have shown, may also exist there, though their lines are not apparent in the solar spectrum.[2] The meteoric theory, besides, accounts satisfactorily for the position of the spots on the solar disk, the relative position of the faculæ, heaped up behind the spots by the inrush of meteoric matter in a direction contrary to that of the solar axial rotation, the spot farthest in advance being the last to disappear, owing to its being in the most favourable position for catching the meteors that remain as the stream is gradually thinning off. Perhaps we might even venture to suppose that the sun's spots, once formed by the fall of external meteors, would subsequently become the channels by which the condensed residue of the jet eruptions found its way again into the sun's heated interior.

27. Even if the meteoric and cometary theory of sun-spots is unsupported by direct evidence, it must be allowed, as Proctor says, to be a strange coincidence, that in 1843, a year of minimum sun-spot area, a remarkable sun-spot, 74,000 miles in diameter, made its appearance on the Sun's disk three months after the perihelion passage of Hubbard's comet—a phenomenon which Schwabe regarded as an anomaly, and not to be looked for as the general cause of the spots of his cycle.[3]

It is also noticeable, as somewhat confirmatory of a connection between sun-spots and comets, that in general unusually large numbers of comets precede or accompany the years of maximum sun-spot, very few non-periodic comets being visible at the time of minimum sun-spot.[4] It has besides

[1] The acceleration of this comet is, I believe, still "sub judice."

[2] Schellen, 'Spectrum Analysis,' p. 411.

[3] 'Light Science.' Proctor. Vol. ii.

[4] Hahn, 'Ueber die Beziehungen der Sonnenfleckenperiode zu meteorologischen Erscheinungen,' p. 178.

been calculated that chemical action is insufficient to account for the protracted emission of the sun's enormous heat and light, whilst meteoric action depends on independent evidence. Sir W. Thomson said (before he abandoned the theory), that the former could only generate 3000 years' heat, while the latter would account for 20,000,000 years' solar heat. Helmholtz has endeavoured to explain this continued emission of heat upon the assumption that the sun is constantly contracting, and has shown that the shrinking of the sun's diameter by $\frac{1}{10000}$ part of its present length would generate an amount of heat competent to cover the total solar emission for 2000 years. Proctor unites the two theories, and appears to think "the combined effect of contraction and the arrival of meteoric supplies would account for that steadiness of emission which forms so important a characteristic of solar action."[1]

It must be remarked that if, as the meteoric and cometary theory assumes, the sun-spots are regarded as perforations in the photosphere, through which the sun is fed, as it were, with meteors, a process strikingly analogous to that of firing-up in a furnace, the accompanying eruptive phenomena of jets and prominences in the Sierra may be assumed to be caused by the increased tension of the gases within the solar bubble, produced by the introduction of such quantities of foreign material.

28. So far the arguments in favour of the meteoric origin of sun-spots would appear to be fairly satisfactory. There is, however, one apparently *insuperable* objection to the notion that the sun's heat is chiefly derived from the fall of meteors, viz., the discovery by the late well-known French astronomer, Leverrier, that the amount of intra-Venusial matter capable of being projected into the sun does not amount to more than would suffice to maintain the total solar radiation for four years! It may, however, be argued on the other hand that the sun is continually moving in space, and therefore probably meeting with fresh supplies of meteoric matter, so that it need not necessarily be dependent merely upon the small amount that exists at any *given moment* in its immediate neighbourhood. Besides, it is quite possible that though the sun's heat may be *principally* due to contraction, the periodic secular variations in it, such as those which are believed to accompany the different phases of sun-spot activity, may be caused, though not necessarily instantaneously, by fluctuations in the supply of meteoric matter. Though the meteoric theory in its original form has been abandoned by its chief promoter, Sir W. Thomson, it has lately been revived in a modified form by Dr. Arthur Schuster, F.R.S., a well-known solar observer, by whom no doubt it will be further developed in the future.

29. Meanwhile Professor Young's theory of the constitution of the solar envelopes, and the mode in which sun-spots are formed, may be provisionally adopted as the one which best accords with the facts hitherto ascertained. It may be observed that Professor Young's notion that the sun-spots are

[1] The 'Sun.' Proctor, p. 459.

openings in the photosphere caused by the descent of matter from the region above it, coincides with those of Secchi and Zöllner, which regard them as places where the matter erupted from the metallic protuberances, sinks back upon the photosphere and occupies the cavities or depressions in the photospheric matter displaced by its own gravity. The only thing still wanting to complete the theory, is a satisfactory answer to the question—What is the cause of the approximately regular sub-annual and secular fluctuations in the frequency of, and area occupied by, the solar spots? No theory of sun-spot formation can be considered perfect, until it accounts satisfactorily for these periodical changes, and as the preceding theory makes them out to be secondary phenomena directly depending for their production on the metallic protuberances, the problem is in this case merely transferred to the latter phenomena, the variations in whose frequency and area approximately correspond with those of the spots themselves, thus affording an additional proof of the close connection between the two.[1] The question therefore finally resolves itself into the following, viz.: "What are the causes which lead to the semi-annual and secular changes in the number and size of the protuberances and jet eruptions? When this question receives a satisfactory and conclusive answer, the whole science of solar physics will have advanced an immense step beyond the position it at present occupies.

30. But it may be asked, how does the preceding résumé of the facts and theories connected with sun-spot formation help us to discover in what way they, or rather the physical changes in the solar atmosphere which regulate their frequency and area, affect the meteorology of the earth. In reply to this, we would remark, that several of the facts alluded to are decidedly calculated to favour the notion of an inverse relation between the amount of solar radiated heat and the frequency and area of sun-spots. First, the fact already noticed regarding the amount of absorbing vapour above the photosphere, at the different epochs of protuberance and spot frequency, and secondly an induction from a consideration of the probable proportion of solar energy transformed into radiant heat at the different epochs of solar activity, and therefore of sun-spot frequency. In regarding this latter point we may assume, to start with, that the total amount of *available* solar energy is practically constant during finite periods. For even if we imagine the solar energy to be maintained by continuous contraction, we must suppose it to go on regularly, and not by fits and starts.

Now, how does this available solar energy manifest itself? In two ways. First, in the activity by which the heated metallic vapours and hydrogen gas are elevated above the general level of the photosphere, from whence after their temperature has been considerably lowered by their increased radiative capacity in these regions, they subsequently sink back

[1] The parallelism is not absolute, however, nor could this be expected, since certain protuberances being purely *hydrogen* have nothing to do with the spots. If the metallic protuberances be considered alone the correspondence is more complete. The time of minimum sun-spot, for example, is characterised by an almost total absence of *large* metallic protuberances.

to form the spots and faculæ respectively; secondly, in radiant heat and light.

31. Now if this available solar energy remains constant, it can readily be understood how an excess in either of the two ways in which it is manifested, necessarily implies a corresponding defect in the other, and vice versâ. According to this notion therefore, we should expect to find the radiation in excess of the average in years of small activity, *i.e.* in years of minimum sun-spot, and in defect of the average in years of great activity, that is in years of maximum sun-spot.

32. It seems, then, that most of the evidence hitherto adduced from observations of the physical condition of the solar surface favours the preceding hypothesis. We shall have occasion subsequently to bring forward evidence from the physical conditions that prevail on the terrestrial globe, amongst others an induction from Messrs. Blanford and Eliot's recent theory of cyclone generation, which powerfully supports the same hypothesis. It may be remarked that several leading physicists, notably Professor Balfour Stewart, and Mr. J. Norman Lockyer, strongly incline to hold the opposite view, viz., that solar radiation is *greatest* when there are *most* spots, and vice versâ. They arrive at this conclusion by supposing in the first place, that greater solar activity, as evinced by a greater number of prominences and sun-spots, indicates more rapid combustion in the solar furnace and *therefore* more radiation; and secondly, that the greater number of cyclones in the tropics (and *other storms* in the extra-tropics according to Professor Stewart) implies greater activity in terrestrial meteorological conditions, and so the expenditure of more direct solar heat to produce it. The relations between barometric pressure in the tropics and the frequency and area of sun-spots recently established by Mr. F. Chambers, are also cited in favour of the same hypothesis, but the considerations involved with regard to this element, we propose discussing later. In the meantime it is evident that while the majority of physicists, are in favour of some connection between the different phases of solar activity and a variability in the amount of solar radiation, there is at present a marked division of opinion as to whether the relation is *direct* or *inverse*.

33. For the present we will abandon any further reference to theories founded on telescopic and spectroscopic observation alone, and proceed to examine what progress has been made towards a solution of this interesting problem, by direct observation of the amount of solar radiation, and by comparison of air-temperature and other meteorological elements indirectly due to solar radiation, for different years of the sun-spot cycles. We must not forget, however, that in dealing with the question of any presumed connection between solar and terrestrial meteorology, there are certain terrestrial phenomena, notably terrestrial magnetism and the Aurora Polaris, which appear to have both a direct and indirect connection with the sun; and also that, in endeavouring to trace a connection between solar and terrestrial phenomena, we cannot confine our attention solely to a diagnosis of sun-

spots, and the possibly very limited changes which the solar physical conditions contemporaneous with their periodical variations produce in terrestrial climate.

34. The connection between the sun and the earth is a very complex one, and besides the regularly recurring (1) diurnal, (2) seasonal, and (3) annual effects due to (1) the force of attraction, and the diurnal rotation of the earth, (2) the fixed inclination of the earth's axis to the plane of the ecliptic, and (3) the change in the absolute distance of the sun from the earth due to the eccentricity of the orbit, embraces effects due to (1) the period of solar axial rotation, (2) the relative position of the sun and moon with respect to the earth, and (3) the physical condition of the sun's surface with respect to spots, jets, and prominences, height of atmosphere, brightness of photosphere, &c.; which, though in some cases subject to regularly recurring periods of variation, in others are liable to abrupt changes, which occasionally are evidently related to equally sudden and abnormal phases of terrestrial meteorological, and magnetical phenomena. In attempting, therefore, to estimate what terrestrial effects can be regarded as having a well-established connection with sun-spots or any other periodically recurring condition of the solar surface, we should expect to find any one effect due to a single cause, so masked by effects due to variations in several of the other influences at work, as to necessitate our enquiring into all the effects due to each disturbing influence respectively, and endeavouring to separate from the complex total the precise effects both qualitative and quantitative, corresponding to that one cause alone.

35. The importance of discovering the true origin and nature of sun-spots and the causes of their periodicity, would however be considerably increased, were we to find any decided and universal coincidence between their phases and those of terrestrial weather; for even granted that such a coincidence did not necessarily imply the existence of any direct correlation of cause and effect, we might still search for some common '*vera causa*' capable of producing or influencing both phenomena simultaneously.

36. We have already alluded to the connection found to exist between the secular variations in terrestrial magnetism and the eleven-year period of solar spots. This forms but a portion of a still larger cycle of 55½ years, which exists in an equally marked degree in both phenomena. This connection, first noticed by Wolf and Sabine, was for some time discredited, but has now been proved beyond all possibility of doubt by Professor Loomis of Yale College, U.S.,[1] and still more recently by Professor Hermann Fritz of Zurich in his magnificent prize essay written for the Haarlem Society of Sciences in 1878.[2] Such an intimate connection between periodic variations in terrestrial magnetism and solar spots, is a strong collateral proof in favour of the existence of some similar connection

[1] 'American Journal of Science and Arts,' 1870–73.

[2] Ueber die Beziehungen der Sonnenflecken zu den meteorologischen und magnetischen Erscheinungen der Erde, von H. Fritz. Haarlem, de Erven Loosjes, 1878.

between variations in terrestrial weather and solar disturbances. I have already observed that according to Professor Balfour Stewart, the majority of the meteorological disturbances produce and govern the corresponding variations in terrestrial magnetism. It matters little to us, however, in our present incomplete knowledge of these elements, which is the cause and which the effect, so long as the connection between them is strong enough to enable us by examining the periods of magnetic variation to know where to look for corresponding meteorological disturbances. In any case it is probable that to nearly every period of magnetic variation (and they are sufficiently numerous and far more easy to determine than their meteorological analogues), there is a corresponding meteorological period, and thus by a process of induction, having learned where to look for our meteorological periodicities, we may, after hunting them out, be able finally to trace them back to their primary cosmical causes.

Through what agency meteorological disturbances cause similar disturbances in the intensity and direction of terrestrial magnetism is but partially understood. In fact, as regards this subject we are, as it were, on the threshold of one of the unknown, though still possible developments of the meteorology of the future. It has, however, frequently been observed that the magnetic pole, the pole of greatest cold, and the pole of the winds, are nearly coincident. The equatorial calms or wind equator, together with the magneto-dynamical and thermal equators (the two latter in addition to the general correspondence of their intermediate lines of equal magnetic and thermal intensity), also exhibit a remarkable coincidence.

It is possible, therefore, as Professor Balfour Stewart thinks, that the rarefied upper convection currents of the atmosphere, generally denominated the "Anti-trades," which are known to exhibit a tendency to converge towards the pole of the winds, may act as conductors of electricity from the magnetic equator to the magnetic poles. As the regions of greatest auroral intensity are approximately coincident with the magnetic poles, the idea entertained by De La Rive, the great Swiss electrician, that this phenomenon is due to the meeting and silent discharge between the opposite electricities with which the equatorial currents and the earth are respectively charged, is in complete accordance with, and to all appearance a natural consequence of, the theory held by Professor Stewart. According to this view the Aurora Polaris should, *ceteris paribus*, approximately constitute a measure of the amount of electricity conveyed to the wind- and magnetic-poles by the equatorial convection currents. Any increase, therefore, in the amount of electricity conveyed by these currents should be indicated by a corresponding increase in the number, brilliancy, and magnitude of the Aurora Polaris. The conditions under which this quantity should rise to a maximum are not easy to determine. Either an excess or defect of solar radiation *may* be the cause. Professor Loomis evidently thinks the former, for he thus explains the cause of the annual inequality of auroras. "The unequal frequency of auroras in the different

months of the year depends partly upon the amount of electricity present in the upper air, and partly upon the humidity of the air by which this electricity may be discharged. The supply of electricity must be greatest when the evaporation is most rapid, that is in summer, and this is probably the reason why in North America auroras are more frequent in *summer* than in *winter*."[1] The secular maximum, however, which is coincident with the maximum of solar spots, he does not attribute to the indirect effect of any increase of temperature and evaporation, but rather to disturbances in the solar electric currents, directly causing both frequency of spots and abnormal displays of the aurora. The question here naturally suggests itself, Why not attribute the secular changes in auroral frequency to a secular variation in the same influences as those by which the annual changes are supposed to be caused, instead of having recourse to a direct solar magnetic influence? Did we do so at once on the hypothesis put forward by Loomis to account for the annual inequality, we should infer that temperature and evaporation were greatest in years of maximum auroral frequency, *i.e.* in years of maximum sun-spot.

It may, however, be objected to Professor Loomis's hypothesis, that it leaves out one very important factor in the production of auroral displays, viz., the presence of ice. Humidity and a high temperature are doubtless necessary for the production of the electricity and its discharge, but the visibility of the phenomenon depends of course on its luminosity, and this, according to De La Rive, is a direct function of the resistance which the reunion of the two electricities encounters, on account probably of the congelation of particles suspended in the air, which constitute the haze invariably accompanying this phenomenon. M. De La Rive even infers that secular changes in the auroral frequency may be caused by secular changes in the accumulations of ice in the neighbourhood of the polar regions. For the Aurora Polaris being only the luminous effect of the electric discharges which take place around the poles between the ground and the vapours that are carried thither, it is necessary, in order to the production of this effect, that the discharges should meet on their route with icy particles, and that consequently the ground itself must be covered with ice. At periods therefore when the regions situated round the magnetic pole are covered with less ice than usual, the discharges may take place, but they will be little or not at all luminous.

On the other hand, an unusual accumulation of ice in these regions would without any additional supply of vapour probably cause a decided increase in the frequency and brilliancy of the visible Auroræ, and from the irregularity of the discharges introduced by the increased resistance give rise at the same time to those large deviations of magnetic declination which usually accompany these phenomena.[2] It seems quite possible then

[1] Loomis's 'Meteorology,' p. 198.

[2] It has been remarked in connection with the same idea that the neighbourhood of the Alps may influence the frequent displays of Aurora seen in Northern Italy.

that the secular changes in auroral and magnetic disturbances which correspond directly with the secular changes in sun-spot frequency may be partly due to variations in the amount of polar ice introduced by coinciding secular meteorological changes. Accordingly we should expect to find a preponderance of ice at the maximum epoch of sun-spots, and a corresponding deficiency at the minimum epoch.

Now from the investigations of Dr. Chavanne, of Vienna (Petermann's Mittheilungen, 1874, pp. 134–245), as reviewed by Professor Fritz in his monograph already referred to, as well as other tables furnished by different investigators for the amount of ice round the pole, in northern rivers, and floating in the Atlantic, the above relation is found to be generally true. Moreover the results obtained by Drs. Köppen and Hahn from a comparison of the air-temperature in different years for a large portion of the Northern hemisphere naturally lead to the same conclusion.

It would, of course, be absurd to suppose that a variation in the amount of ice near the poles is the *sole* cause of changes in the magnitude and frequency of a phenomenon like the aurora, and the magnetic disturbances which accompany it, both of which often have a true cosmical character, the former being manifested at the poles, and the latter all over the globe at the same absolute time. It is quite possible, however, that the presence of ice may favour the visibility and magnitude of the phenomenon, while the main causes that contribute towards its production may be partly of an indirect meteorological and partly of a direct magnetic nature.

Inability to follow up with precision a line of inductive proof like the preceding only arises from our imperfect knowledge of the way in which magnetic and meteorological phenomena react upon one another, and by no means argues the inability of observing the numerous instances that exist of analogous periods of variation in the two phenomena.

37. By accumulating correlative analogies of this description we may ultimately furnish ourselves with such an array of proofs of the exact correspondence between the two phenomena, that when the method by which the one produces or affects the other is thoroughly understood, we may without hesitation regard the variations in the one as a complete index to similar variations in the other. Before long, therefore, we may come to regard the magnetic needle as a sort of meteorological index, the variations of which may be taken to indicate corresponding changes in terrestrial weather, either coincident with, or following upon, those conditions of the convection currents of the atmosphere, which, according to Balfour Stewart, directly affect the weather and indirectly the magnetism of the globe.

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4. **Evans, J.** Address at the Loan Collection Conference. Section, Phys. Geog. Nature, xiv. p. 114 et seq. (*rv*).
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16. **Tarry, H.** Histoire de l'atmosphère. Les Mondes.
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17. Accelerated transmission of weather maps. 'Nature,' xv. p. 107 (*rv*).
18. Archiv for Mathematik og Naturvidenskab. Vol. i. [It has papers on meteorology.]
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34. Nature, xv. p. 193 to end (*rv*); xvi. (*rv*); xvii. p. 1–176 (*rv*).

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40. The Treasury Report on Meteorology. 'Nature,' xv. p. 425–427 (*rv*).

41. Weather notes. 'Nature,' xv. p. 343 (*rv*). [Refers to United States and Australia.]

42. Weather warnings for watchers. By the Clerk himself. With a concise table for calculating heights. 8vo. pp. 96. 1*s*.

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1. [**Archibald, E. D.**] Solar spots and terrestrial meteorology. The Behar Herald, April 23, 1878, p. 3, 4; April 30, p. 3, 4; May 7, p. 4, 5; May 14, p. 1, 2, 3; July 16, p. 34 (*ra*). [The paper is not signed.]

2. **Broun, J. A.** Cosmic meteorology. 'Nature,' xviii. p. 126–128 (*rv*).

3. **Buchan, A.** 'Nature,' xvii. p. 506 (*rv*).

4. **Buys-Ballot, C. H. D.** Rapport sur les observations simultanées. Folio. Utrecht. (Lib. Met. Soc.)

5. **Buys-Ballot, C. H. D.** Rapport sur la question 31 du programme du deuxième Congrès international des météorologistes qui doit se reunir au mois d'avril 1879. Folio. Utrecht, 1878. (Lib. Met. Soc.)

6. **Buys-Ballot, C. H. D.** Rapport sur la réduction des moyennes des observations en vraies moyennes. Folio. Utrecht. (Lib. Met. Soc.)

7. **Chambers, Fred.** Sun-spots and weather. 'Nature,' xviii. p. 567–568. [Refers to temperature and to Bombay in India.]

8. **Collins, J. J.** The American storm-warnings. 'Nature,' xviii. p. 4–7, 31–34; 61–63 (*rv*).

9. **Edwin, R. A.** Fourth report upon the experimental system of storm-warnings in New Zealand. Folio. Wellington. (Lib. Met. Soc.)

10. **Faye.** La météorologie cosmique. Ann. Bureau des Longitudes for 1878.

11. **Fonvielle, W. de.** La prévision du temps.

12. **Guillemin, A.** The forces of nature. Trans. by Mrs. Lockyer. 1877–8. [Contains chapters on meteorology.]

13. **Hann, J.** Ueber die Aufgaben des Meteorologie der Gegenwart. 8vo. pp. 26. Wien, 6*d*. (Lib. Met. Soc.)

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15. **Kingston, G. T.** Instructions for recording rain, snow, weather and miscellaneous phenomena. 4to. Toronto. (Lib. Met. Soc.)

16. **Kingston, G. T.** Instructions to observers at ordinary stations of the second series. 4to. Toronto. (Lib. Met. Soc.)

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Lamont, L. v. See 1878, 25.

Laughton, J. K. See 1878, 43.

Ley, W. Clement. See 1878, 43.

Lockyer, Mrs. See 1878, 12.

18. **Loomis, E.** Contributions to meteorology. Am. Journ. Sci., July. [Refers mainly to barometric conditions in U.S. and Europe.]

19. **Mathieu (de la Drôme).** Le Triple Almanach indicateur du Temps pour 1879. 16mo. Paris. (Lib. Met. Soc.)

20. **Meldrum, C. J.** 'Nature,' xvii. p. 448, 449, 450 (*rv*).

21. **Meteorol. Soc. Scotland.** Journal. Nos. 51-56. 8vo. Edinburgh.

22. **Meteorol. Congress.** Report to the permanent Committee of the first International Meteorological Congress at Vienna on Atmospheric Electricity, Maritime Meteorology, Weather Telegraphy. 8vo. London. (Lib. Met. Soc.)

23. **Meteorology.** Annalen d. Hydrographie u. Maritime Meteorologie.

24. **Meteorology.** Annuario. Società Meteorologica Italiana. Edited by D. Ragona. Vol. i. 8vo. Roma. 6*s*.

25. **Meteorology.** Beobachtungen meteorologische u. magnetische d. k. Sternwarte in München f. 1877. Edited by L. v. Lamont. 8vo. München.

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30. **Mohn, H.** Bericht abgestattet an den 2ten meteorologischen Congress in Rom. 8vo. Privately printed. (Lib. Met. Soc.)

31. **Myer, A. G.** The Weather Case, or Farmer's Weather Indicator. 'Nature,' xviii. p. 621-625. [Circular issued by the Signal Service of the United States Army.]

32. **Neumayer, G.** Address to German Assoc. at Munich on the progress of meteorology. 'Nature,' xvii. p. 313-314 (*rv*).

33. **Oborny, J. A.** Die Meteorologie und Wettertelegraphie im Dienste d. Landwirthschaft. 8vo. Leipzig. 2*s*.

34. **Preston, Rev. T. A.** Report on the phenological observations for the year 1877. Q. Journ. Meteorol. Soc., p. 54-70. (Read Dec. 19, 1877.) [England.]

Ragona, D. See 1878, 24.

35. **Rossi, U. S. de.** Il microfono nella meteorologia endogena. Studii ed esperienze. Bull. de vulcanismo Italiano. 8vo. Rome. (Lib. Met. Soc.) [Endogenous meteorology means earthquake knowledge.]

36. **Scott, R. H.** The American storm warnings. Nautical Mag. (Lib. Met. Soc.)

37. **Skalweit, H. C. W.** Magnet. Beobachtungen in Memel n. e. Versuche d. Unregelmässigkeiten im tagl. Gange d. Declinationsnadel a. meteorologischen Zurückzuführen. 4to. Königsberg. 4*s*.

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39. **Tarry, H.** Échange de télégrammes météorologiques entre l'Europe et l'Afrique. 4to. 2nd ed. Bordeaux. (Lib. Met. Soc.)

40. **Thomson, G. S.** The weather. 'Nature,' xix. p. 148. [Clifton in England.]

41. **Wild, H.** Bericht über Art. 10 des Programms des 2ten internationalen Meteorologen Congresses in Rom. 8vo. St. Petersburg. (Lib. Met. Soc.)

42. Catalogue des ouvrages d'Astronomie et météorologie found in the principal libraries of Belgium. pp. 640 and xxiii. 7*s*. 6*d*.

43. The Meteorological Society's lectures. 'Nature,' xix. p. 177, 178. [Abstracts of lectures by J. K. Laughton on "Air temperature, its distribution and range," and by W. Clement Ley, on "Clouds and weather signs."]

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2. **Blake, C. C.** Weather calculations from March 1st, 1879, to April 1st, 1880; with an appendix of new astronomical laws. Folio. Decatur. (Lib. Met. Soc.)

3. **Blanford, H. F.** Report on question 26 of the programme for the Meteorological Congress of 1879. 8vo. Privately printed. (Lib. Met. Soc.)

4. **Brault, L.** Question No. 34 du programme du deuxième Congrès météorologique de Rome, relative à la construction et à la publication des Cartes synoptiques. Folio. Rome. (Lib. Met. Soc.)

Brocard. See 1879, 30.

5. **Bruhns, C.** Bericht über die Fragen 8, 15, 33 und 35 des Programms für den Meteorologen-Congress in Rom, 1879. 8vo. Leipzig. (Lib. Met. Soc.)

6. **Bureau Central Météorologique de France.** Instructions météorologiques. 8vo. Paris. (Lib. Met. Soc.)

7. **Burgess, A. H.** Storm warnings. 'Nature,' xix. p. 313-314 (*rv*).

8. **Cantoni, G.** Osservazioni meteoriche a servizio dell' agricultura. 8vo. Rome. (Lib. Met. Soc.)

9. **Croll, James.** Climatic effects of the present eccentricity. 'Nature,' xx. p. 602 (*rv*). [Temperature.]

10. **Denza, F.** Alcune notizie intorno al Congresso Meteorologico Internazionale tenutosi a Parigi dal 24 al 28 Agosto 1878. 8vo. Rome. (Lib. Met. Soc.)

11. **Depretis, A.** Discours prononcé a l'ouverture du 2me Congrès météorologique international de Rome. 8vo. Rome. (Lib. Met. Soc.)

12. **Ebermayer.** Bericht über die Fragen 18 und 21 des Programms für den Meteorologen-Congress in Rom, 1878. 8vo. Leipzig. (Lib. Met. Soc.)

13. **Ellis, Wm.** The recent weather. 'Nature,' xx. p. 313 (*rv*). [Weather here means temperature and sunshine at Greenwich.]

14. **Ferrari, A.** On two new meteorological works. 'La Natura,' iii.

15. **Fisher, O.** Climatic effects of the present excentricity. 'Nature,' xx. p. 577–578; 626 (*rv*). [Temperature.]

16. **Fonvielle, W. de.** La prévision du temps. 12mo. Paris. 1·5 marks.

17. **Friesenhoff, G.** Die Wetterlehre, oder praktische Meteorologie. 8vo. Wien. 2·4 marks.

18. **Fritz, H.** Die Beziehungen der Sonnenflecken zu den magnetischen und meteorologischen Erscheinungen d. Erde. 4to. Haarlem. 12*s*.

19. **Hann, J.** Bemerkungen und Verschläge zu den gegenwartigen Grundlagen der Wetterprognose. Zeits. f. Meteorol. 8vo. Wien. 0·4 mark. (Lib. Met. Soc.)

20. **Hann, J.** Bericht über die Frage:—Wie können die Meteorol. Institute sich d. Land- und Forstwirthschaft förderlich erweisen? 8vo. Wien. 0·8 mark.

21. **Hann, J.** Bericht erstattet dem zweiten internationalen Meteorologen-Congress über die Beobachtungen auf höhen Bergen und im Luft-Ballon. (Punkt 30 des Programms.) 8vo. Vienna. (Lib. Met. Soc.)

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24. **Hellmann, G.** Plan für meteorologischen Beobachtungen im Dienste der Landwirthschaft des Königreichs Preussen. Landwirths. Jahrb. viii. (Lib. Met. Soc.)

25. **Hill, E.** Climatal effect of eccentricity. 'Nature,' xx. p. 626 (*rv*). [Temperature.]

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27. **Kopp, H.** Einiges über Witterungs-Angaben. 8vo. Braunschweig. 3·6 marks.

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Laughton, J. K. See 1879, 34.

Ley, Rev. W. C. See 1879, 34.

29. **Liburnau, J. R. R. L. von.** Bericht für den zweiten internationalen Meteorologen-Congress über die Frage: Wie können die meteorologischen Institute sich der Land- und Forstwirthschaft förderlich erweisen? (Zu Punkt 35 des Programms.) 8vo. Vienna. (Lib. Met. Soc.)

30. **Loomis, E.** Mémoires de Météorologie dynamique, exposé de résultats de la discussion d. cartes du temps des États-Unis. Trans. by Brocard. 8vo. pp. 16 and 214. Paris. 4*s*.

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32. **Lorenz, J.** Wald, Klima u. Wetter. 8vo. pp. viii. and 274. München. 3*s*.

33. **Lorenz, J.** Bericht über die Frage: Wie können, etc. [as in 1879, 29.] 8vo. Wien. 0·8 mark.

34. **Mann, R. J., J. K. Laughton, R. Strachan, Rev. W. C. Ley, G. J. Symons,** and **R. H. Scott.** Modern Meteorology. 8vo. London. 4*s*. 6*d*.

35. **Marié-Davy, H.** Meteorological registers. Journ. de Phys., April—'Nature,' xx. p. 320–323 (*rv*).

36. **Marriott, Wm.** Reduction of Meteorological Observations. Trans. Watford Nat. Hist. Soc., ii. p. 197–208. (Read May 13; pub. Dec.)

37. **Mascart.** On the inscription of meteorological pheuomena, particularly electricity and pressure. Journ. de Physique. Oct.

38. **Meteorol. Conference.** Bericht über eine Konferenz in Hamburg zur Besprechung einiger Punkte, welche, auf den Betrieb und die Einrichtung des Witterungs und Signal-Dienstes in Nordwest Europa Bezug haben, December 1875. 8vo. Hamburg. (Lib. Met. Soc.)

39. **Meteorol. Conference.** Minutes of Proceedings of the Intercolonial Meteorological Conference held at Sydney on the 11th, 13th, 14th Nov. 1879. Folio. Sydney. (Lib. Met. Soc.)

40. **Meteorol. Congress.** Congrès International de Météorologie tenu à Paris du 24 au 28 août 1878. 8vo. Paris. (Lib. Met. Soc.)

41. **Meteorol. Congress.** Rapports sur les questions du programme du deuxième Congrès météorologique international de Rome. 8vo. Rome. (Lib. Met. Soc.)

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43. **Meteorol. Congress.** Report of the proceedings of the second international meteorological Congress at Rome, 1879. 8vo. London. (Lib. Met. Soc.)

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48. **Meteorology.** Annalen d. Hydrographie u. maritimen Meteorologie. 4to. Berlin. 3*s*.

49. **Meteorology.** Bureau central météorologique de France. Instructions météorologiques. 8vo. Paris. 2·2 marks.

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51. **Meteorology.** Jahrbuch, etc. [as in 1873, 36.] Edited by Guido Schenzl. Bd. vii. 8vo. Budapest. 10*s*.

52. **Meteorology.** Repertorium f. Meteorologie. Ed. by H. Wild. 4to. Bd. vi. Heft 1. 7·7 marks. Heft 2. Pp. 426. 17 marks.

53. **Meteorology.** Schweizer meteorologischen Beobachtungen. Bd. xvi. Edited by R. Wolf. 4to. Zürich. 9*s*.

54. **Meteorology.** Symons's Monthly Meteorological Mag. 8vo. London.

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56. **Mohn, H.** Grundzüge d. Meteorologie. Die Lehre d. Wind u. Wetter. 2nd ed. 8vo. Berlin. 5·4 marks.

57. **Moseley, H. N.** Notes by a Naturalist on the *Challenger*. 8vo. London (*rv*).

58. **Müller-Pouillet.** Lehrbuch d. Physik u. Meteorologie. 8th ed. by Pfaundler. Bd. ii. 8vo. Braunschweig.

59. **Neumayer, Geo.** Denkschrift über einige Vorschläge zur Durchführung des in dem Punkte 31 des Programms für den zweiten internationalen Meteorologen-Kongress angeregten Gedankens, mit besonderer Beziehung auf die Gegenden der Erde in höheren südlichen Breiten. 4to. Hamburg. (Lib. Met. Soc.)

60. **P.** Pigeons and weather warnings. 'Nature,' xx. p. 363 (*rv*).

61. **Pernet, J.** Bericht über die Frage 16 des Programms für den Meteorologen-Congress in Rom, 1879. 8vo. Leipzig. (Lib. Met. Soc.)

Pfaundler. See 1879, 58.

62. **Pittei, C.** Congresso Internazionale di Meteorologia a Roma. Rivista Marittima. (Lib. Mét. Soc.)

63. **Pittei, C.** Rapports présentés au deuxième Congrès météorologique international de Rome. 8vo. Florence. (Lib. Met. Soc.)

64. **Poey, A.** Comment on observe les nuages pour prévoir le temps. 3rd ed. 8vo. pp. 5 and 176. Paris. 4*s*. 6*d*. (Lib. Met. Soc.)

65. **Preston, Rev. T. A.** Report on the phenological observations for the year 1878. Q. Journ. Meteorol. Soc., p. 42–64. [England.]

66. **Rossi, M. S. de.** La Meteorologia endogena. 8vo. Milano. 7*s*. [Earthquakes.]

Schenzl, Guido. See 1879, 51.

67. **Schültz, A.** Bemerkungen z. d. Berichte über d. Organisation e. meteorolog. Dienstes in Interesse d. Land- u. Forstwirthschaft. 8vo. Berlin. 6*s*.

Scott, R. H. See 1879, 34.

68. **Sidler, W. Z.** Entwicklungs-Geschichte d. modern. Meteorologie. 8vo.

69. **Smyth, Piazzi.** Weather past and to come. 'Nature,' xix. p. 338 (*rv*). [Temperature.]

70. **Spooner, W. C.** The seasons and the crops; their mutual relations. 8vo. Dorchester. (Lib. Met. Soc.)

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Symons, G. J. See 1879, 34; 1879, 54.

71. **Tissandier, G.** Observations météorologiques en ballon. Résumé de 25 ascensions aërostatiques. 8vo. Paris. Pp. 55. 1*s*. 6*d*.

72. **Wettstein, H.** Die Strömungen d. Festen, Flüssigen und Gasförmigen und ihre Bedeutung für Geologie, Astronomie, Klimatologie und Meteorologie. 8vo. Zürich, 1880. [Published in 1879.] 8*s*.

Wild, H. See 1879, 52.

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74. **Williams, W. Mathieu.** A possible consequence of our present weather. 'Nature,' xxi. p. 130–131 (*rv*).

Wolf, R. See 1879, 53.

75. Instructions to meteorological observers issued by the Meteorological Committee. 8vo. Cape Town. (Lib. Met. Soc.)

76. The Meteorological Congress at Rome. 'Nature,' xx. p. 57–59 (*rv*). [Nothing for these notes.]

77. Meteorological Notes. 'Nature,' xx. p. 270, 271 (*rv*). [The subjects referred to are: Loomis's observations on wind and areas of low barometric pressure in New England and on Mt. Washington; the observations at Stonyhurst; and the rain results for New S. Wales.]

78. Meteorological Notes. 'Nature,' xxi. p. 48–49 (*rv*). [The subjects dealt with are: temperature in London; connection between weather and rate of mortality in the Australian colonies; the weather in Iceland and in Victoria.]

79. Meteorological Notes. 'Nature,' xxi. p. 142 (*rv*). [Subjects: typhoon in the China and Japan seas; the weather of Missouri; the temperature of the Atlantic and of the British Isles.]

80. Meteorological Organisations. 'Nature,' xix. p. 514 (*rv*).

81. Weather Charts for the Northern Hemisphere. 'Nature,' xx. p. 381–383 (*rv*).

82. 'Nature,' vol. xix. p. 189 to end (*rv*); vol. xx. (*rv*); xxi. p. 1–196 (*rv*).

83. Royal Society. Catalogue of Scientific Papers, vol. viii. (*rs*).

84. The Weather and its Prediction. 'Quarterly Review,' Oct.

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2. **Bruhns, C.** Die Benützung der Meteorologie für landwirthschaftliche Arbeiten. Mittheil. oekon. Gesells. Sachsen. (Lib. Met. Soc.)
3. **Bruhns, C.** Bericht über das meteorologische Bureau für Wetterprognosen im Königreich Sachsen, 1879. 8vo. Leipzig. (Lib. Met. Soc.)
4. **Bureau Central Météorologique de France.** Instructions pour l'observation des phénomènes périodiques des animaux et des végétaux. 4to. Paris. (Lib. Met. Soc.)
5. **Cantoni, G.** Sù le osservazioni meteorico-agrarii. 8vo. Varese. (Lib. Met. Soc.)
6. **Descroix, L.** Résumé météorologique des années agricoles 1873–1880. Ann. de l'Obs. de Montsouris pour l'an 1881. (Lib. Met. Soc.)
7. **Houzeau, J. C.** Traité élémentaire de Météorologie. 8vo.
8. **Jenkins.** On a connection between meteorological phenomena and the time of arrival of the earth at perihelion. Atti Accad. Lincei, May.
9. **Ley, Rev. W. C.** Aids to the study and forecast of the weather. 8vo. London. (Lib. Met. Soc.)
10. **Loomis, E.** Contributions to Meteorology. 12th No. Am. Journ. Sci., Feb.
11. **Loomis, E.** Contributions to Meteorology. 13th No. Ann. Journ. Sci., July.
12. **M., H.** The U.S. Weather Charts. 'Nature,' xxiii. p. 147 (*rv*). [Nothing in it for these notes.]
13. **Marcet, Wm.** On the influence of altitude with reference to the treatment of pulmonary disease. Brit. Med. Journ. Oct. 2. Read to Brit. Med. Assoc. at Cambridge, Aug. (*ra*).
14. **Marié-Davy, H.** Météorologique agricole. Ann. de l'Obs. de Montsouris pour l'an 1881. (Lib. Met. Soc.)
15. **Mascart.** Sur l'inscription des phénomènes météorologiques, en particulier de l'électricité et de la pression. Ann. Soc. Mét. France, xxviii. (Lib. Met. Soc.)
16. **Meteorology.** Repertorium für meteorologie. Bd. vii. Ed. by H. Wild.
17. **Parkin, John.** Epidemiology; or the cause of epidemic disease, of murrains, of blight, of hurricanes, and of abnormal atmospherical vicissitudes. 2nd ed. 8vo.
18. **Porro, S.** On some recent studies in agrarian meteorology. 'La Natura,' iv.
Poste, E. See 1880, 1.
19. **Preston, Rev. T. A.** Report on the phenological observations for the year 1879. Q. Journ. Meteorol. Soc., p. 1–28. (Lib. Met. Soc.)
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21. **Ramsay, A.** General bibliography of climate, 1485 to 1830. The Scient. Roll, i. p. 11–16. (Lib. Met. Soc.)
22. **Renou, E.** Note sur l'hiver de 1880. Ann. Soc. Mét. France, xxvii. (Lib. Met. Soc.)
23. **Scott, R. H.** Weather forecasting. Brit. Alm. and Comp. for 1881.
24. **Tayler, W. B.** Henry and the telegraph. Smiths. Report for 1878.

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26. **Wilson, Wm.** The ocean as a health resort. 8vo. London.
27. **Wragge, C. L.** Forecasting the weather. (Lib. Met. Soc.) [? date. About 1880.]
28. What is the climate most favourable to the development of civilisation? Annuaire de l'Obs. Bruxelles.
29. Ciel et Terre. 8vo. Brussels. [A popular journal of astronomy and meteorology. Published fortnightly.]
30. International monthly chart for April, 1878. 'Nature,' xxi. opp. p. 304; May, 1878, same vol., opp. p. 377; June, 1878, same vol., opp. p. 500; July, 1878, same vol., opp. p. 565; August, 1878, xxii., opp. p. 36; for September, 1877, same vol., opp. p. 100; Sept. 1878, same vol., opp. p. 249; Oct. and Nov. 1878, same vol., opp. p. 516. Dec. 1878, xxiii., opp. p. 39.
[The maps are loose; the reference to pages may not therefore be correct for some copies. They show the mean temperature, pressure, direction, and force of wind for each month at 7·35 A.M. (Washington time) for a large portion of the northern hemisphere, and for a few places in the southern hemisphere.]
31. Intercolonial Meteorological Conference at Sydney. 'Nature,' xxii. p. 160 (*rv*). [Nothing in it for these notes; relates mainly to arrangements for weather warnings.]
32. International Meteorology. 'Nature,' xxii. p. 307; 471–472 (*rv*).
[The first article is the programme of the International Meteorological Committee meeting at Berne and of the Conference meeting at Vienna. The second gives results of the Berne meeting and the resolutions adopted.]
33. Meteorological Notes. 'Nature,' xxi. p. 265–266 (*rv*). [Clouds, temperature, and pressure; wind charts of the Pacific, Atlantic, and Indian oceans, and waterspout off Cape Spada.]—xxi., p. 384–385 (*rv*). [Meteorology of Bombay; pressure, rainfall, and wind; temperature and rainfall of Austria and Hungary.]—xxi., p. 503–504 (*rv*). [Tay Bridge storm; weather of Canada; atmospheric pressure in U.S.; rates of progress of storm centres.]—xxii., p. 132–133 (*rv*). [Sweden; Tasmania.]—xxii., p. 253–254 (*rv*). [U.S. Missouri; wind and rainfall; Malden island in 4° 2′ S.]—xxii., p. 594 (*rv*). [Thunderstorms, temperature, and barometer; United States; Scotland.]—xxiii., p. 183–184 (*rv*). [The U.S. weather maps; Canada, U.S., and British Isles; temperature; barometric pressure in London; Falkland Islands.]
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35. The United States weather maps, April to July, 1878. 'Nature,' xxi. p. 565–567 (*rv*).
36. The United States weather map, Aug. 1878. 'Nature,' xxii. p. 36–37 (*rv*).
37. The United States weather maps. Sept. 1877. 'Nature,' xxii. p. 100 (*rv*).
38. The United States weather maps. Sept. 1878. 'Nature,' xxii. p. 253–254 (*rv*).

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43. The Scientific Roll. Climate. Vol. i. p. 1–16. 8vo. (Lib. Met. Soc.)

1881.

1. **Archibald, E. D.** On the connection between solar phenomena and climatic cycles. Pt. i. The Scient. Roll: Climate, i. p. 17–37. (Lib. Met. Soc.)

2. **C., H. W.** The recent severe weather. 'Nature,' xxiii. p. 329 (*rv*). [Weather = temperature in Brit. Isles.]

3. **C., H. W.** The recent severe weather. 'Nature,' xxiii. p. 363–364 (*rv*). [Temperature cycles.]

4. **F. M. S.** The recent severe weather. 'Nature,' xxii. p. 363 (*rv*). [Temperature cycles.]

5. **Loomis, E.** Contributions to meteorology. Am. Journ. Sci. Jan. [Wind.]

6. **Meteorol. Council.** Report for 1880. 8vo. Pp. 118. (Lib. Met. Soc.)

7. **Meteorology.** Revista mensual climatologica. Tomo i. 4to. (Lib. Met. Soc.)

8. **M. R. I. A.** The recent severe weather. 'Nature,' xxiii. p. 411 (*rv*).

9. **Preston, Rev. T. A.** Report on the phenological observations for the year 1880. Q. Journ. Meteorol. Soc., vii. p. 13–39. [England.]

10. **Ramsay, A.** General bibliography of climate, 1831 to 1881. The Scient. Roll: Climate, i. p. 38–47; 49–77.

11. Meteorological Notes. 'Nature,' xxiii. p. 322–323 (*rv*). [Wind; Mauritius: Europe.] —— xxiii. p. 470–471 (*rv*). [Europe; Cobham in Surrey; British Islands: Scotland: England.]

12. The Scientific Roll: Climate. Vol. i. p. 17–80. 8vo.

GENERAL NOTES.

1607.

Davis, John. *The Voyages and Works of John Davis, the Navigator.* Hakluyt Soc. Edited by A. H. Markham, 1880. *The Seaman's Secrets.* (*rv*).

(*Page* 308.) A climate is the space included between two parallels wherein the day is sensibly lengthened or shortened half an hour; the climates take the names from such famous places as are within the said climates. The 1st passeth through Meroe, between 12° 45′ and 20° 30′; 2nd, Syene, 20° 30′ and 27° 30′; 3rd, Alexandria, 27° 30′ and 33° 40′; 4th, Rhodes, 33° 40′ and 39°; 5th, Rome, 39° and 43° 30′; 6th, Boristhenes, 43° 30′ and 47° 15′; 7th, Rhipaan Mountains, 47° 15′ and 50° 20′; 8th, Mæotis, or London, 50° 20′ and 52° 10′; 9th, Denmark, 52° 10′ and 55° 30′.

1833.

Ainsworth, W. *Journal of the Royal Geographical Society.* I. (for 1831). 2nd ed. (1833) (*rv*).

(*Page* 211.) Capt. Beechey's expedition noticed that in the Arctic regions in 1826, (*Page* 112) when the weather was settled, the aurora generally began in the W.N.W., and passed over to the N.E., until a certain period, after which it as regularly commenced in the N.E. and passed to the N.W.; whilst in 1827 the appearances of the meteor were as uncertain as the season was boisterous and changeable. The period when this change in the course of the light took place coincided very nearly with that of the equinox.

1851.

Alexander, J. H. (*B.* 4.)

[He says weather on the third day before new moon regulates that on each quarter-day, and that generally of the whole period.]

1853.

Maclaren, C. *Art. America. Encyclopædia Britannica*, vol. ii. (*ra*).

(*Page* 670.) The latitude and elevation of the land in every country, its position in reference to the sea, with the direction of the prevailing winds, are the chief circumstances which determine the nature of the climate.

1859.

English Cyclopædia. (*B.* 4.)

(*Col.* 921.) Almost as soon as the barometer was discovered, it was observed that changes in the height of the mercury corresponded to changes in the weather. The (*Col.* 933) water barometer (1 in. bore) is affected by the weather one hour sooner than the ordinary barometer with half an inch bore, and this one hour before a barometer with ·15 in. bore.

English Cyclopædia. (*B.* 4.)

(*Col.* 967.) The climate of the Greeks corresponded roughly to our latitudes. They indicated in a general way the comparative temperature which a country enjoys by

reason of its smaller or greater distance from the equator. The modern term climate has a wider meaning. It implies all the phenomena which affect vegetation and render a country a fit abode for men and animals. Heat and moisture, properly speaking, constitute climate; but the latter is dependent on the former, while that itself varies originally according to distance from the equator and height above the level of the sea, the results of both co-ordinates being themselves subject to variation from other causes. The other phenomena, such as wind, electricity, &c., affect these constituents of climate; but they require a separate consideration as modifiers of it, according to the view we take of the subject.

1860.

English Cyclopædia. (*B.* 7.)

(*Col.* 599.) Meteorology in its extended sense embraces all physical causes which affect the state of the atmosphere or are affected by it. Hence it is connected with the phenomena of heat and cold, dew, rain, hail and snow, clouds, winds, auroræ boreales and australes, haloes, parhelia, &c. The sense in which Aristotle uses it is still more extensive, comprehending, in addition to what are now called meteors, every affection common to the air and water, with the character of the different parts of the earth and their affections, as winds and earthquakes, and everything incident to such moods of motion.

Grey, Earl de. (*B.* 9.)

(*Page* cxlv.) Meteorology has approached to the character of an exact science. It is now by no means difficult to estimate the climate of any place of which the geographical position is known. The hours of highest and lowest temperature and barometric pressure, the normal height of the mercurial column, and the prevalence of moist air, rain or dryness, much or little wind, can be predicated approximately for any part of the world, although in that particular place no observations may yet have been made. (page cxlvi) Dampier, De Foe, Capper, Flinders, are amongst the contributors to meteorological science. Instruments have been lent by Government to upwards of thirty fishing villages.

1861.

English Cyclopædia. (*B.* 16.)

(*Col.* 165.) Mountains arrest the fleeting clouds; their influence on local climate is all-powerful, and depends upon the direction in which they lie as regards the sun's course, their height, their position upon the surface of the globe, their proximity to or remoteness from the sea, the winds they arrest or give passage to, etc. They have also a climate, or rather a great variety of climates, of their own. Thus, in ascending from the sea towards the summit of the Andes almost every kind of climate is passed through, nearly as completely as if the traveller were to proceed from the equator towards the poles.

[In the latter part of this passage climate seems to mean little more than temperature, while in the former its meaning is more extensive.—A. R.]

English Cyclopædia. (*B.* 16.)

(*Col.* 428.) The phenomena of the seasons may be divided into those which occur yearly and those which are different in different years. We have in every year the same succession of longer and shorter days, with a summer and winter, while the summer of one year is of a higher temperature and is accompanied by finer days than that of another. The unvarying phenomena can be explained by what we know of the sun's (or earth's) motion; the varying phenomena belong to meteorology, and depend upon atmospheric and other circumstances with which we have little or no acquaintance. The earth's axis preserves its direction throughout the whole of the yearly motion. The consequence

is that places which are distant from the equator have very unequal days at different times of the year. The accompanying figure [not reproduced here], which is generally given in connection with the subject, represents the earth in its four principal positions, the sun being at S., and N. being the north pole of the earth; A is at the vernal equinox; the intersection of the equator and ecliptic passes through the sun, and (*col.* 429) days and nights are equal all over the world. B is the summer solstice, when the sun is most above the equator on the northern side; the diurnal circles have more day than night, and have their longest days, and *vice versâ.* C being the autumnal equinox, the phenomena of A are repeated. D is at the winter solstice, when the sun is farthest from the equator on the southern side: the phenomena of B are now reversed, the days being shortest on the north side of the equator. This figure very well explains the variation of days and the main reason for the phenomena of seasons in the extra-tropical parts of the earth. It is evident, speaking of the northern hemisphere, the sun being above the equator gives not only longer days, but greater altitudes, more powerful light and heat, and more of it in duration. It does not serve for the tropical climates, as the days and nights are so nearly equal throughout the year that seasons are caused more by the effects of the winds (which are very regular, and depend mainly upon the sun's position) than by changes in the direct action of the sun's light and heat. The seasons are not so much a summer and winter as a recurrence of dry and wet periods—two in each year.

FitzRoy, R. (*B.* 17.)

(*Page* cli.) Simultaneous daily observations were started in 1857 at a number of stations in the British Isles and on the Continent. Storm-warnings were suggested (*page* clii) before 1836, but were not commenced till September 1860. The first warnings were given on Feb. 6th, 1861.

Galton, F. (*B.* 18.)

[His paper is simply a suggestion of a method of making meteorological charts so as to give a bird's eye of the various phenomena of rain, &c.]

NOTE.—*B.* is the contraction for bibliography: the number is that of the item under the year mentioned in each case.

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GENERAL NOTES.

1863.

Beardmore, N. (*B.* 2.)

(*Page* 1.) The British Meteorological Society was founded in 1850. Continuous (*Page* 2) observations are made at many stations. Brookes's photo-recording system is (*Page* 3) a great improvement. The perturbations in the sun's photosphere appear to react on the earth's atmosphere. Wolf has discovered a secular period of eleven years in the sun's spots. The method of recording and signalling by telegraph simultaneous readings which prevail over wide areas has of late years assumed a very prominent position. In July 1856 Le Verrier introduced the system of having the state of the weather at different points in France telegraphed to the Imperial Observatory, where the observations were reduced and issued in the form of a daily bulletin, and soon after (*Page* 4) he extended his area for returns over a large portion of Europe. It was soon found that the principal meteorological disturbances were propagated in a direction from W. to E.; and that it was important that Great Britain should be included in the scheme, a matter which was accomplished by Adm. FitzRoy early in 1860. [See 'Notes,' 1861, FitzRoy.] Synchronous observations are of especial importance. Regular observations are made by Quetelet, in Belgium. Kreke and Buys-Ballot collect observations from 11 stations in the Netherlands. In Sweden there are 21 (*Page* 6) stations. In Norway three or four. Denmark is represented by Oersted. In North Germany there are 90 or 100 stations. Austria has about 140, and Russia 30. Observations are made at Athens. Sinobas has established about a dozen stations in Spain. There are many in France, as also in Switzerland. Lisbon has an observatory. North America has upwards of 500 stations. Canada has its observatories. Scotland has (*Page* 8) about 60, and Ireland several stations. In 1861 the spring, summer, and autumn were warm, dry, and genial over Europe and North America. At the head-waters of the Nile and in India there were deluging rains. In 1860 North America and Europe had both cold and wet summers, while the plains of India experienced a severe drought.

Bellingham, W. (*B.* 3.)

(*Page* 111.) He believes that a belt of vapour passes alternately from pole to pole in about forty days, and that this gives rise to periodicity of atmospheric phenomena at intervals, varying according to the locality. At London it is ten and thirty days.

Tomlinson, C. (*B.* 36.)

[The title of the paper is not as given at p. 55. It should be: An experimental examination of the so-called storm-glass.] The storm-glass did not, I believe, hold (*Page* 93) rank as a scientific instrument until it was introduced by Admiral FitzRoy. In the Report for 1862, issued by the Meteorological Department of the Board of Trade, it is stated that the chemical mixture in a so-called storm-glass varies in character with the direction of the wind and electrical tension; and that temperature affects the (*Page* 94) mixture much, but not solely. In the article on Camphor Storm-glasses in (*Page* 95) Ure's Dictionary of Arts, edited by Mr. Robert Hunt, it is stated on the

authority of Dr. Parrion that the weather-predicting qualities of the instrument are false; light and temperature being the conditions which affect it. Some years ago I purchased a storm-glass at an instrument maker's shop, and received with it a paper which stated that it would correctly indicate the coming rain, high wind, storm or tempest; that the indication for fine weather was that the substance would be low and smooth at the bottom; and that experience had proved the instrument to be useful in (*Page* 96) the prognostics of the changes that take place in the weather, if properly made. I have been in the habit of observing this instrument for some years past, and had long ceased to regard it as of any value as a weather indicator. While experimenting on camphor I was induced to conclude that heat only was concerned in the storm-glass phenomena. [A series of experiments are described in support of this view, which need not be detailed here, since they have no bearing on meteorological (*Page* 108) phenomena.] The conclusion drawn from these experiments is that the storm-glass acts as a rude kind of thermometer, inferior to that in ordinary use for most of the purposes of observation.

Willis, R. (*B.* 38.)

(*Page* lv.) The system of simultaneous meteorological observations was organised in 1840. The meteorological department of the Board of Trade was created in 1854. The Kew Observatory was commenced in 1842.

1864.

Buchan, Alex. *On the weather conditions which produce large crops of turnips and cereals. Journ. Scot. Meteorol. Soc.*, I. pp. 149–154. No. IV. Oct. (*rv*).

[The paper refers to Scotland, but is of general application, except as regards the periods. There are no particulars for general notes, but some will be found under several of the elements.]

Forbes, Sir J. S. *Address on Meteorology. Journ. Scot. Meteorol. Soc.*, I. pp. 104–116. Read Jan. 1864; published in July, 1864 (*rv*).

(*Page* 107.) The first 'Barometer Guide, and how to foretell the Weather,' was (*Page* 109) published by Admiral FitzRoy in 1857. Espy's 'Fourth Report' was (*Page* 110) published in 1854. Human health and life are servile to all the skyey (*Page* 113) influences. Since March 1862 there have been 45 warnings issued by Admiral FitzRoy almost uniformly followed by gales more or less serious. The stations directly communicated with now by telegraph amount to about 80, and from these more than twice as many receive messages. Instruments have been lent to many thousand selected merchant vessels since 1854, from whose logs trustworthy observations extending over many years have been obtained. It is remarkable that nothing has been done to obtain reliable data for calculating the average return from the soil under different circumstances of the weather or at different dates.

Garner, R. (*B.* 8.)

(*Page* 114.) An increasing deterioration of the atmosphere in towns and mining districts may be estimated by means of plants thus: 1. In the smallest degree of impurity trees are destitute of the leafy lichens; and Ericæ, the Scotch fir and the larch die. 2. Next, the common laurel, the Deodara cedar, the Irish arbutus, the laurestinus and the yew die. 3. The Araucaria, the Thuja, the common cedar, the mezereon and the Portugal laurel die. 4. The common holly, the rhododendron, the oak and the elm die. 5. Annuals still live, and the almond, poplar and many roses thrive, fruit trees are barren, and peas unproductive. 6. Hieracia, Reseda lutea, the

elder, some saxifrages and sedums thrive, while many syngenesious and cruciferous weeds still luxuriate.

Meldrum, C. *Proc. and Trans. Meteorol. Soc. Mauritius*, VI. Report read Dec. 29, 1862 (*rv*).

(*Page* 64.) The total number of members in the Meteorological Society of Mauritius is 80, or nearly double what it was three years ago. Within the last few years the science of meteorology has received more attention than it ever did before. There is not a civilised country in the world which is not through its government, its scientific bodies and numerous observers, busily engaged in meteorological pursuits both on land and at sea. This was in a great measure brought about through the exertions of Captain Maury. At his suggestion a conference of meteorologists was held at Brussels in September 1853, the object of which was to adopt a uniform and universal system of observation at sea over the whole globe. The result was that the governments of the various countries represented on that occasion, such as Great Britain, France, America, Denmark, Prussia, Holland, &c., adopted measures to carry the recommendations of the conference into effect. Special offices were created for the purpose of obtaining observations, collecting and discussing them, and publishing (*Page* 65) the final results; and already a large body of highly useful information has been published, especially in England, under the direction of Admiral FitzRoy. But meteorological research is not confined to the sea. All along the coasts of Europe and America, as well as at numerous inland stations meteorological observations are either being already taken or observatories being established. By means of the electric wire the central observatory, or meteorological office, of each country is in daily and hourly communication with a network of smaller observatories extending to the remotest corners of the land and constantly keeping those at head-quarters informed of the changes of wind and weather that are taking place on all sides of them. The central observatories again are in electric communication with each other; so that at certain hours on each day it is known in London, Paris, &c., what winds and weather were experienced a few hours previously over the greater part of Europe. If there should be reason to suppose that a gale or storm is at hand despatches are sent to all the sea-ports warning the shipping of the threatened danger. Meteorology is thus becoming a science of the highest practical utility to navigation, agriculture and other national interests. These are powerful motives for establishing and maintaining so many observatories and transmitting the results to a central station from which they are again sent forth to the world. In this instance considerations of public and private welfare come to the aid of science. But besides this incentive to meteorological observation over an extensive area, there is also the pleasure derived from tracing effects to their causes, and extending our knowledge of the laws of nature. In this point of view meteorology is likely to become one of the most popular and interesting of the physical sciences. Not many years ago it would have seemed absurd to suppose that it was possible that a person in London should have placed before him every morning a chart showing the barometric pressure, the temperature of the air, the direction and force of (*Page* 66) the wind, and the state of the weather at all the principal towns and sea-ports of Europe on the previous day; and yet we now know that this is not only practicable, but that, if it has not already been effected, it has at least been strongly recommended, and will, no doubt, be carried into execution. Now what could be more interesting than by means of such charts to watch the atmospheric changes occurring from day to day over thousands of miles; to observe the respective tracts of high and low temperature, and high and low atmospheric pressure; where cloud and sunshine respectively prevailed; where rain fell and where it did not fall; where tempests and thunderstorms took place, and where, on the other hand, the sky was serene; to note the varying force and direction of the aerial currents with their attendant phenomena; to trace the rise and progress of gales,

storms, and hurricanes; in short, to be the daily spectator over a wide area of the operations of nature in that wonderful laboratory the atmosphere. Nor is it to Europe and America that the system of meteorological inquiry set on foot some years ago is confined. India had long ago been distinguished for its labours in this branch of science, observatories having been established at many stations, and many officers, civil and military, co-operating in a general plan of observation, and these observatories are still busily at work. Within the last few years also the subject has been taken up by the Australian Colonies, in which several observatories have been established at the public expense, with numerous branch observatories in connection with them; the whole being placed under the general superintendence of officers appointed and paid by the Government. And it appears that a few months ago a meteorological commission appointed at the Cape of Good Hope to report upon the meteorology of that colony, recommended that ten stations should be supplied with instruments for systematic observations by competent persons, who, we learn, have already entered upon their duties. By increasing the number of observatories and extending the system to all parts of the habitable world, (*Page* 67) while at the same time observations are daily and hourly taken in all navigated parts of the ocean, the day will come when the atmosphere can be contemplated as a whole, and the mutual relations of the phenomena occurring in it be more clearly perceived and understood. All that is wanted in the first place is to have a sufficient number of reliable observations taken at the same moments of absolute time at numerous points over the whole accessible globe, and to have them continued for a lengthened period. It is towards the realisation of this object that the efforts which are now being made in so many and so widely distant countries are tending, and when it shall have been attained, meteorology will become one of the most useful of the modern sciences. (*Page* 68). It is universally admitted that the future progress of meteorological science will depend upon the active co-operation of all countries, each contributing towards the general result. From its special position Mauritius is one of the most important of all (*Page* 69) the meteorological stations. The Meteorological Society of Mauritius (*Page* 74) was established on August 1, 1851.

(*Page* 80.) Every phase of weather has its meaning, which only requires to be read aright to convey important information.

Meldrum, C. *Proc. and Trans. Meteorological Soc. Mauritius*, VI. Paper read June 3, 1863 (*rv*).

(*Page* 177.) Mauritius is so favoured by geographical position that with a knowledge of the atmospheric changes which take place in the neighbouring seas we can, so far as the experiment has yet been tried, tell with certainty when a storm exists, where it exists, and often in what direction it is travelling, although its distance from us may be nearly 2000 miles. As yet there has not been a single exception to this rule.

Scoresby-Jackson, R.E. *On the Importance of the Study of Medical Climatology. Journ. Scot. Meteorol. Soc.*, I. pp. 25–40. Published Jan. 1864 (*rv*).

(*Page* 25.) Meteorology is closely allied to the science of medicine; it holds a prominent position in social science; and it enters into the calculations of the political (*Page* 27) economist. Uniformity of action must be observed, which may be most easily attained by following the instructions at the back of each schedule. The instruments used should be in good order and subject to frequent comparison with standards. [The details given as to the influence of climate on disease belong to Man.] (*Page* 28) Five day means are best adapted to medical climatology. Averages of a number of years, or of seasons, or of months, are not safe guides in medical meteorology. There is occasionally a tendency on the part of observers who are wedded to certain

localities to hide little climatal defects by drawing averages from long periods. Hence it happens that what are called exceptional years frequently occur at such places.

Scoresby-Jackson, R.E. *Report of the Medico-Climatological Committee. Journ. Scot. Meteorol. Soc.*, I. pp. 120–121 (published July, 1864); pp. 154–157 (published Oct.) (*rv*).

[Nothing in them for general notes.]

1865.

Becquerel, A. C. *Journ. Scot. Meteorol. Soc.*, I. Published July, 1865 (*rv*).

[The name is there misprinted Becqueral, and the paper is the translation of one in 'Comptes Rendus,' lx. p. 136.]

(*Page* 235.) The influence of forests upon climates depends (1) on the extent of the forests; (2) on the height of the trees and their species, according as they have deciduous or persistent leaves; (3) on the power of evaporation possessed by their leaves; (4) on their capacity of being heated or cooled like any other body placed in the air; (5) on the nature of the soil and subsoil. The climate is improved by bringing the (*Page* 237) land under cultivation, by draining unhealthy marshes, and by planting trees on mountains and on all soils not suited for pasture and tillage.

Dumas. (*B.* 15.)

(*Page* 950.) Lavoisier fully appreciated the method of foretelling weather by means of simultaneous observations. He thought the weather could always be foretold twenty-four hours in advance. He had no idea of the telegraph. The proposal to use telegraph was first started in 1852.

Leverrier, U. J. J. (*B.* 28.)

(*Page* 1318.) The intention of collecting observations by telegraph was to use them for forecasts. The first collection of simultaneous records in France was on February 19, 1855. I dispute the statement as to the direction from which Italian storms usually come.

Matteucci. (*B.* 30.)

(*Page* 892.) The idea of having a central office for collecting simultaneous observations by telegraph for purposes of prediction was started in 1858. I started a similar plan for Italy in 1864. The great storms which attack the British Isles from the west rarely fail to reach Italy, so that nearly all predictions of these come right. Those threatening from Spain rarely extend to Italy.

(*Page* 1314.) First forecast issued was on July 31, 1861. Two years after, Leverrier followed FitzRoy's example in France. Strongly in favour of forecasting storms only.

Poey, A. (*B.* 36.)

(*Page* 1279.) Early in the 17th century simultaneous meteorological observations were organised by the Accademia del Cimento. The Meteorological Society of Mannheim first organised an extensive meteorological correspondence, and several plans of the same kind have since been carried out in France, United States, &c. In 1840 the Royal Society proposed the establishment of as many meteorological observatories as possible in all parts of the world.

Scoresby-Jackson, R.E. *Report of the Medico-Climatological Committee. Journ. Scot. Meteorol. Soc.*, I. pp. 182–183 (published in Jan.); pp. 210–212 (published in April); pp 241–243; p. 244 (published in July); pp. 276–277 (published in Oct.) (*rv*).

[Nothing for general notes.]

1866.

Becquerel, A. C. (*B.* 2.)

[The translation of this paper given in the Journ. Scot. Meteorol. Soc. was published in July, 1865; and the notes are entered under 1865. The volume is dated 1866, but contains the quarterly numbers issued from Jan. 1864 to Oct. 1866.]

Buchan, A. (*B.* 5.)

[This paper was published in July 1865. It refers mainly to Scotland, and contains nothing for general notes.]

Buchan, A. (*B.* 6.)

[This paper was published in Jan. 1866. It refers to various European countries, and contains nothing for general notes.]

Buchan, A. *Hints to Observers regarding Instruments. Journ. Scot. Meteorol. Soc.*, I. pp. 300–303. Published in Jan. (*rv*).

[Nothing for general notes.]

Buchan, A. *Meteorological Characteristics of the Winter of* 1865–6. *Journ. Scot. Meteorol. Soc.*, I. pp. 358–366. Published in July, 1866 (*rv*).

[There is nothing for general notes. It refers mainly to European countries.]

Forbes, Sir J. S. (*B.* 13.)

[This paper was published in Jan. 1864, under which year the notes are entered.]

Leverrier, U. J. J. *On Storm Signals and Weather Warnings. Journ. Scot. Meteorol. Soc.*, I. pp. 366–368. From *Bulletin International*, April 26. Published in July (*rv*).

(*Page* 366.) On Jan. 16, 1860, a letter was sent to the Minister of Marine in which it was stated that to signal a storm as soon as it should appear at any point of Europe, to follow it in its march by means of the telegraph, and to send warning of its approach in good time to the coasts which it will visit, should be the ultimate end to be reached by the system which we carry out. The means for carrying out this scheme were not granted. Some time after, FitzRoy began a system of warnings on a different principle. He undertook to foretell the probable weather for the following day to the coasts of the United Kingdom. About the middle of 1863 M. Duruy promised the (*Page* 367) required assistance. While organising a service operations were limited to the system of forecasts begun by FitzRoy. The system of absolute forecasts is beset with difficulties which prevent its being adhered to entirely. We cannot tell the direction the storm will take; hence we cannot send definite forecasts to particular localities. Hence we have adopted a system intermediate between the warning of an approaching storm and prevision thereof. We receive daily observations made at 8 A.M. in winter and 7 A.M. in summer from 21 French and 42 foreign stations. We receive in the evening observations made at 6 P.M.; twelve being from French stations. This second series is necessary as a check on the first. It indicates any change that may have taken place since the morning in those parts over which it is particularly desirable to keep an outlook. When no atmospheric disturbance has occurred the observations of the evening, in their relation to those of the morning, enable us in general to forecast (*Page* 369) the weather of the following day. A greater number of evening despatches are wanted. Telegrams are sent to 73 French ports.

Mitchell, A. *Journ. Scot. Meteorol. Soc.*, I. Published in Jan. (*rv*).

(*Page* 304.) The 'Ark o' the Cluds' is not always regarded as a forerunner of bad weather. When it runs north and south the aftercome is not so much dreaded as when it is stretched between any of the other points (Galloway). The weather-gaw sometimes indicates good weather. When it is seen in the east its consequences are less dreaded.

The weather's taking up now,
For yonder is the weather gaw;
How bonny in the east now!
Now the colours fade awa'.

(*Page* 305.)

Grumphie sees the weather,
And grumphie sees the wun', etc.

(Galloway).

Gif the lavrock sings afore Cannelmas,
She'll mourn as lang after it.

(Galloway).

(*Page* 306.)

Ne'er trust a July sky.

(Shetland).

Mottez. (*B.* 29.)

(*Page* 620.) Latent electricity enters into the constitution of water, but in different quantities in the three conditions. Probably all meteorological phenomena are explicable by this principle.

Scoresby-Jackson, R. E. *Report of the Medico-Climatological Committee. Journ. Scot. Meteorol. Soc.*, I. pp. 306–307 (published in Jan.); pp. 335–336 (published in April); pp. 370–371 (published in July); pp. 388–389 (published in Oct.) (*rv*).

[Nothing for general notes.]

Journ. Scot. Meteorol. Soc. *Number of Meteorological Stations established in different Countries in Europe.* I. p. 368. Published in July (*rv*).

(*Page* 368.)

Russia	25	Prussia, etc.	36
Norway and Sweden	11	Austria	109
Denmark	11	Italy	32
Holland	9	Switzerland	86
Belgium	9	Spain and Portugal	10
Scotland	81	Turkey	3
England	54	Greece	1
Ireland	12	Malta	1
France	65		

1867.

Buchan, A. (*B.* 6.)

(*Page* 1.) Meteorology was originally applied to the consideration of all appearances in the sky, astronomical as well as atmospherical, but the term is now restricted to that department of knowledge which treats of the phenomena of the atmosphere that relates to weather and climate, their relations to each other, and the laws to which they are subservient. Owing to the complexity of the phenomena and the manifold influences by which they are modified and determined, it would be beyond the power of the human intellect to give a perfectly satisfactory explanation of them. From the nature of the subjects which make up the science of meteorology, we may infer that they occupied (*Page* 2) men's minds from a remote antiquity. The splendid panorama of the sky and the variations of temperature through the days and seasons, together with the other atmospheric changes constituting the weather which affect in so powerful a manner the necessities and comforts of man, are of a nature well-fitted to arrest his attention.

Hence the appearances which were found by experience to precede changes of weather were eagerly recorded and handed down in the sententious form of weather-proverbs. In this way many valuable facts were ascertained and passed current from hand to hand, so that there is perhaps no science of which more of the leading facts and inferences have been so long incorporated into popular language. Aristotle was the first who collected, in his work 'On Meteors,' the popular prognostics of the weather. A number of these were derived from the Egyptians who had long studied the science as a branch of astronomy, while a large number were the fruit of his own observation. Theophrastus, one of Aristotle's pupils, next took up the subject, classifying the commonly received opinions of the weather under four heads, viz., the prognostics of rain, wind, storms, and fine weather. He made no attempt to explain phenomena. Cicero, Virgil, and a few other writers also wrote on the weather, but made no substantial additions to our knowledge. The treatise of Theophrastus contains nearly all that was known down to comparatively recent times. Partial explanations were attempted by Aristotle and Lucretius, but their explanations were necessarily vague owing to ignorance. No progress was made until proper instruments were invented for making real observations with regard to the pressure, temperature, humidity, and electricity of the atmosphere. (*Page* 3) Torricelli's discovery of the barometer in 1643 was undoubtedly the first step in the progress of meteorology to the rank of a science. The value of the barometer as an indicator of the weather gave an additional impetus to the study of the science. Sanctorio's invention of the air thermometer in 1590 laid the foundation of a salutary revolution in the science, since it pointed to an exact determination of the temperature of the air, which is by far the most important element of weather in relation to our welfare. Fahrenheit was the great improver of the thermometer. The hygrometer is an instrument of great value in meteorology as indicating the quantity of vapour in the (*Page* 4) air, and inferentially the changes of weather dependent thereon. From the period of the invention of these instruments the number of meteorological observers was greatly increased, and a large body of well authenticated facts of the utmost value began to be collected. The climates of particular parts of the earth were inquired into and compared together, and the science made great and rapid advances by the investigations undertaken by distinguished philosophers into the laws which regulate atmospheric phenomena. The publication of Dalton's 'Meteorological Essays,' in 1793, marks an epoch in meteorology. It was the first instance of the principles of philosophy being brought to bear on the explanation of the complex and varied phenomena of the atmosphere. (*Page* 5) Well's 'Theory of Dew' (1814), must always be regarded as one of the greatest contributions to meteorology. In 1823, Daniell published his 'Meteorological Essays and (*Page* 6) Observations.' It is to be expected that the discovery of the relations of atmospheric vapour to heat, will soon be turned to account in explaining many questions of meteorological enquiry. Humboldt's treatise on 'Isothermal Lines,' published in 1817, marks an important epoch in experimental meteorology. The temperature of one country differing materially from that of neighbouring countries, has an important influence in causing unsettled and stormy weather in both countries at that time. The establishment of meteorological societies during the last twenty (*Page* 7) years, has contributed in a high degree to the solid advancement of the science which, more than any other, depends on extensive and well-conducted observations. In this respect, the United States stands pre-eminent, the observers there numbering about 800. Great Britain has about 150. In Austria, Switzerland, France, Prussia, Italy, Russia, the Netherlands, and other European countries, meteorology is being widely cultivated. Austria has 108 stations, and Switzerland, 83. A special object of meteorological enquiry, is to ascertain the degrees of heat, cold, and moisture peculiar to different localities, and the usual periods of their occurrence, with a view to discover their effects on the health of the people, and on different agricultural (*Page* 8) products. One fruit of the multiplication of meteorological stations, is the

prediction of storms, and the foretelling of the weather. It is impossible to overestimate the value of storm warnings to the shipping interest. In the north temperate zone, observation shows that storms almost invariably come from some westerly point, and thence follow an easterly course. Hence, in the United States, it is easy to warn seaports of the approach of storms. America is thus favourably circumstanced for carrying out effectually the system of storm warnings. On the contrary Great Britain, France, and the rest of W. Europe, are unfavourably situated to allow of timely warning being given of coming storms, because, if no warning be sent till the storm has made its appearance, it is too late for the western seaports. But in Europe, stormy weather is almost always accompanied with a diminution of atmospheric pressure, the centre of which, after traversing more or less of the Atlantic ocean, arrives on the coast of Europe. The existence of this depression is made known by the barometer when the maximum is still at a considerable distance out at sea; and collateral information pointing to an advancing storm is to be obtained from the direction of the (*Page* 9) wind, and the cirrus clouds. Here, then, we have materials for foretelling the approach of storms on the west coast of Europe. For though we cannot arrive at the degree of certainty of the American predictions, and telegraph to the coasts that a storm is actually seen advancing on them, yet from the premonitions afforded by the barometer, the wind, and the cirrus cloud, we can warn them to prepare for a storm which is likely to visit them. The giving effect to this idea constitutes the splendid contribution to practical meteorology made by Admiral FitzRoy in February, 1861, by the system of storm warnings which has since been adopted by almost every country in Europe. Owing to the present state of our knowledge, a degree of uncertainty is inseparable from the storm warnings based on these premonitions, which does not attach to predictions, based on storms actually observed. The 'Bulletin International,' of Le Verrier, published daily, must be regarded as the latest (*Page* 10) important step taken in the progress of meteorology. In the schools of the United States of America, meteorological observations and the keeping of meteorological registers form a part of the common education of the people. Also in the higher schools of France, and some other European countries, systematic instruction is communicated on this subject; but in this country, meteorology is generally neglected in our educational system. There are a few exceptions. Meteorology has been taught for upwards of thirty years in the Dollar Institution, and the example has been followed at Stonyhurst, the Grammar School of Aberdeen, and at other places (*Page* 75). It is this [viz., the degree of divergence of extremes], which makes the most important distinction among climates, both as regards animal and vegetable life. On man, especially, the effect is very great. The severity of the strain of extreme climates, is shown in a striking manner by the rapidly increasing death rate, according as the difference between the July and January temperatures is increased. Thus the mortality is 8 per cent. greater in England than in Scotland, the climate of the latter country being more equable or insular in its character; and it is found that on advancing into the continent of Europe, that the more extreme the climate becomes, so much the more is the death rate increased. [Climate here means temperature.] Since (*Page* 105) clouds are subject to distinct modifications from the same causes which produce the other atmospheric phenomena, the face of the sky may be regarded as indicating the operation of those causes. The ancient meteorologist was content with discerning the face of the sky in order to predict the coming weather. It is to this chiefly that the weather-wise sailor and farmer still look, and their predictions are frequently more correct than those made solely by instruments. The best (*Page* 106) system of weather prediction comprises both methods. Small groups of regularly-formed and arranged cirrus scattered over the sky often accompany fair weather and light breezes. When a storm of wind has passed and the sky has cleared, should a few fine cirrus clouds be seen slightly blown back at their eastern ex-

tremities, the storm has in all likelihood really past, and fair weather may with some confidence be expected, since the dry polar current has already begun to prevail overhead. When cumuli are of moderate size and height, well defined (*Page* 107) curved outline, and appear only during the day, they indicate a continuance of fine weather. The gradual lifting of the stratus from the ground, its conversion into cumuli, and the disappearance of these indicate a continuance of the finest (*Page* 140) and serenest weather. As synchronous charts present the principal elements of the weather at a given instant, they may be regarded as successive (*Page* 165) photographs of storms in their passage across the earth's surface. An examination of weather changes over large portions of the surface of the globe from day to day leaves a deep and lasting conviction on the mind of the essential unity of the earth's atmosphere, and *à fortiori* the oneness of comparatively so small a portion as that of Europe in respect of the intimate relations of its different parts, and their absolute dependence on each other. We have seen waves of temperature creeping over that continent apparently so vast that only a mere fragment of one of them could be exhibited by the whole continent at one time; and the same remark applies with equal force to the waves of barometric pressure which pass across it. We are very ignorant of the causes of these vast atmospheric changes. Meteorology is eminently the science of observation and averages, and before those inquiries now raised regarding the general movements of the atmosphere can be satisfactorily and adequately discussed, it is indispensable that the field of observation be extended, so as to embrace the whole of the northern hemisphere. The present state of our knowledge of the science may be thus put. Given in any locality an excess or diminution of atmospheric temperature, and an excess or diminution of atmospheric moisture, we know the atmospheric changes which will take place in restoring the equilibrium thus disturbed, and can to a considerable extent turn this knowledge to account in predicting the weather. But as regards the specific conditions out of which those great atmospheric disturbances take their origin we know little or nothing; and it is to acquire this all-important knowledge that we urge the extension of the field of observation so that synchronous charts of the northern hemisphere might be constructed (*Page* 180) which would supply the information desiderated. More magnetic observatories are wanted, so that synchronous magnetic charts might be made for comparison with similar meteorological charts. If this was accomplished, and the relation between these atmospheric elements discovered, the magnetic and electric states of the atmosphere and the aurora might take their place among the most valuable prognostics of the weather. Weather is the condition of the air at any time as regards heat, moisture, wind, rain, cloud, and electricity, and a change of weather implies a change in one or more of these atmospheric elements. The craving of the public for a knowledge of these changes is indicated by the prognostics of every country, which, amid much that is shrewd and of practical value, embody more that is vague and not a little that is absurd; and by the readiness with which newspapers seize upon prognostications of fine or of stormy weather weeks or months beforehand. No prediction of the weather, at least in the British Isles, can be made for more than three or perhaps only two days (*Page* 190) beforehand, and any attempt at a longer prediction is illusory. Still, guesses may be formed which are not without value. All prediction based on solar or other astronomical causes, if not misleading, is useless. The only safe guide we can have in attempting to forecast the weather for some time are averages based on terrestrial observations. Of this class may be mentioned the interruptions which occur in the regular march of temperature in the course of the year.

Rikatcheff. (*B.* 55.)

(*Page* 5.) In 1865 FitzRoy's system of meteorological observations and telegraphing was established in Russia.

1868.

Buchan, A. (*B.* 4.)

(*Page* 1.) Meteorology is the science of the weather. Meteorology took its modern (*Page* 3) rise from the invention of the barometer by Torricelli in 1643, the thermometer by Sanctorio in 1590, Fahrenheit's improvements in 1714 and De Saussure's (*Page* 9) researches on hygrometers. Austria has 110 stations. Monthly isobarometric (*Page* 43) lines may justly be regarded as furnishing the key to all questions of mete- (*Page* 129.) orological inquiry. The year 1867 was so remarkable for illustrations of violent alternations of heat and cold, drought and rain, brilliant sunshine and the dullest weather, as well as for the many great storms which swept all parts of the globe, that it (*Page* 138.) may well be regarded as the *annus mirabilis* of meteorology. Though all meteorologists now agree in thinking that daily telegrams should not be attempted, yet a great deal of positive information regarding the suitableness of the coming weather for travelling, farming operations, the growth and ripening of crops, and for other objects and purposes of human life, may be most certainly concluded from daily weather telegrams received from a wide field of observations. It will be evident from the relations of the pressure and temperature of the atmosphere and of the winds, that daily observations, particularly barometric, from a number of well-selected points in Europe, would supply sufficient data from which really trustworthy conclusions could be drawn regarding the weather from day to day over any part of Europe in which for the time we might take an interest. If Reuter and private individuals would add particulars of the weather to their telegrams we might form a tolerably accurate estimate of the probable (*Page* 331) productiveness of the harvest in grain-producing countries. Investigations appear at present to point to a connection between the position of the planets on one hand and the sun's spots, terrestrial magnetism, and the aurora on the other. Nothing, however, could be inferred from such a connection, even were it conclusively established, that could be turned to account in predicting the weather (*Page* 332) likely to occur in a particular country within a specified time. It is an opinion which has been long and popularly entertained that the changes of the moon have so great an influence on the weather, that they may be employed with considerable confidence in prediction. That the moon's changes exercise an influence so strongly marked as to make itself almost immediately felt in bringing about fair, or rainy, or settled, or stormy weather, an examination of meteorological (*Page* 335) records sufficiently disproves. The next class of prognostics are of a more certain character, being taken from those indications or appearances which experience has shown to be the precursors of a change of weather, or rather they are the first indications or beginnings of these changes. Perhaps the very earliest indication of a change from dry to wet weather might be obtained from observations of the polari- (*Page* 339) sation of the atmosphere. It is by a careful observing and recording of the lesser changes of the weather from day to day, that the approach of the greater changes included under storms of wind, rain or snow, may to some extent be known beforehand. It is not by a single observation made at one time that an isolated observer can best draw conclusions regarding the weather likely to happen, but from the character of the changes which have been silently going forward for some time. Hence it is desirable to set down in a pictorial form the different observations as they are made, so that the eye may take in at once the whole of the changes which are going forward. The Rev. R. Tyas's handy little annual, 'How to use the Barometer,' is calculated to be popularly useful for recording pictorially and in tables the successive changes of the weather from (*Page* 341) day to day. Mr. Meldrum sent a note to the daily papers when it was concluded from the Mauritius observations that a storm was abroad, stating its position and probable course from day to day. No case of failure has occurred since these notices

began to be sent to the press. This shows what may be done at an isolated station in the ocean; in other words what may be done by ships at sea. The reduction of the ocean statistics of meteorology has now become a question of pressing importance. In discussing meteorological ocean statistics referring chiefly to tropical and subtropical regions, the most important points to be determined are the following: 1. The daily range of the barometer for the different months as applicable to the different parts of the ocean, or, better still, the law of its variation according to season, latitude, and proximity to large masses of land. 2. The mean monthly barometric pressure of the different seas chiefly traversed by ships given for every ·05 in., or, if possible, every ·025 in. of mean pressure. 3. The deviation from the mean pressure of the month which may be regarded as an amount of disturbance sufficient to be considered as indicative of a storm (*Page* 342) at no great distance. 4. The mean direction and force of the wind for the different months. This is no doubt a vast problem, which it will take many years to work out. In regions such as Great Britain an isolated observer cannot with a like certainty draw conclusions from his own observations regarding the approach of storms and other weather changes. But he may almost, if not altogether, attain to the same degree of certainty if he be assisted by a sufficient staff of observers well distributed over W. Europe; and be able, when he considers it necessary, to communicate with them through the telegraph. In his letter of June 15th, 1865, to the Board of Trade, Gen. Sabine states that he had examined the warnings given on our coasts during the two years ending March 31st, 1865, and found that in the first year 50 per cent., and in the second year 73 per cent., were right. The improvement he ascribes to increased (*Page* 343) experience. A number of the places warned were not favourable situations for receiving timely warnings, being too near the west coast; but if the warnings sent to places more favourably situated were examined fewer failures would appear. Thus, of 100 warnings sent to the north coast of France in the winter of 1864–5, 71 were realised; and in the winter of 1865–6, 76. Of 100 storms which occurred 89 were signalled during the first winter, and 94 during the second winter. The first and chief source of failure was the want of a day and night watch maintained on the west coast of Ireland; whereas this is the first requisite of any system of storm warnings for the British Isles, as pointed out by R. Russell. With observations at 7 a.m. and 2 p.m. only, some storms would have passed some stations before warnings could be issued. (*Page* 344) The occasional late arrival or non-arrival of telegrams was also a source of failure. There were too few stations on the Continent to the east and south-east of Great Britain. If, then, allowance be made for the failures which arise from these causes, we have the explanation of every one of the ten storms which were not signalled out of the 93 which occurred on the N. coast of France in the winter of 1864–5, and of the 6 not signalled out of the 99 which occurred during the following winter. Hence it follows that, practically, the approach of any storm which visits Great Britain may be signalled some time before it reaches the different ports. There is thus no difficulty in carrying on a system of storm warnings (*Page* 345) in this direction. The practical difficulty lies in securing that no warning be sent except to those places at which the wind will rise to the force of a gale. If this happened uniformly over the whole region included at any time within the low barometric pressure, marking out the atmospheric disturbance of which the wind storm is one of the accompaniments, or if a certain wind force invariably attended on a certain pressure in each storm, then the problem of storm warnings might be regarded as completely solved. But the force of the wind at a particular place depends upon the relative differences of pressure as observed simultaneously at two other places between which it lies. To determine these relations for any place for the next 30 hours, so that from the result warnings might be framed for that place, is a problem which admits only of an approximate solution; any exact solution, and exact rules framed from such solution, to guide us in issuing storm warnings being impossible. It suffices if the number

of successful warnings be sufficient to warrant the practice of issuing them. What is wanted are: (1) a day and night watch at Valentia; (2) the telegraphing to London immediate notice of storms in N.-W. France and Spain, W. Ireland, W. and N. Scotland; (3) power to use the telegraph wires at discretion. The only difficulty in carrying it out is the expense.

Strachan, R. (*B.* 37.)

(*Page* 3.) Weather forecasting depends upon definite principles. FitzRoy gave ample (*Page* 4) explanation of the principles involved in forecasting the weather, in official reports on the Meteorological Office, but especially in his 'Weather Book.' Fine weather (*Page* 14) occurs with uniformly high pressure. If the law of barometric variations (*Page* 15) were known, or if any law as regards barometric maxima and minima could be established, then the forecasting of weather could be reduced to a very accurate (*Page* 16) system—it would be a simple mechanical problem. Sir John Herschel long ago saw this. No such law is yet recognized. FitzRoy has practically proved that great storms can be predicted from one to three days beforehand in the present state of meteorology. In the British Isles the transition from a maximum to a minimum of atmospherical pressure does not take place generally in less than 24 hours, while it frequently extends over many days. The diurnal range is trifling and not taken into account. Hence the probabilities of being able to rely on the transitions for one day and of forecasting weather therefrom must be great; but for two days they must be less, for three days much less, while for more than three days they can have very little dependence. (*Page* 17.) Forecasts depend upon: 1. Law of wind direction in relation to pressure. 2. Extent of barometric differences. 3. Rate and direction of barometrical changes. If we suppose the probabilities in favour of each of these conditions as 9 to 1; the value of the probability of a daily forecast being correct will be $\frac{9 \times 9 \times 9}{10 \times 10 \times 10} = \frac{729}{1000}$ or 7 to 3 nearly. If two days be taken the probabilities for No. 3 must be reduced. Let it be supposed 7 to 3 then the value of a forecast for two days would be 6 to 4 nearly, or $\frac{567}{1000}$. If three days be attempted the probabilities for No. 3 will be, say 5 to 5. Then the value of a forecast for three days will be $\frac{405}{1000}$, that is, oftener wrong than right. No importance is attached to this hypothetical calculation. [It applies to British (*Page* 18) weather, but may be taken to be of general application.] The forecasting of rain, snow, hail or fog, of cloudy overcast or clear sky, of hot or cold weather and such like weather features, must be rather a matter of shrewd guessing. The direction and strength of the wind, the most important characteristics of weather, may be considered (*Page* 20) to be within the scope of rule. The key to FitzRoy's method of forecasting weather was identical with the law of wind in relation to pressure, as stated by Ballot. (*Page* 24) Meteorological knowledge is not yet sufficiently systematized. There is abundance of material, but books continue to be crammed with assumed rules. Hence it is more than ever needful to sift facts by resting all laws, principles and rules on demonstration. J. D. Forbes (Brit. Assoc. Rep. vol. i.) said what is true yet, that there is prevalent a too generally erroneous notion that meteorology as a science has no other object but an experimental acquaintance with the condition of those variable elements which from day to day constitute the general and vague result of the state of the weather at any given spot; not considering that while such heterogeneous elements can be of little avail, when viewed as groups of facts towards forwarding any one end of the science or giving us any precise knowledge regarding it, yet that the careful study of the individual points when grouped together with others of the same character may afford the most valuable aid to scientific generalization.

Zenger, C. W. (*B.* 43.)

(*Page* 433.) Argues that the moon influences temperature and pressure according to the moon's position relatively to the earth and sun; the temperature is highest and pressure lowest when the obliquity of the moon's orbit is greatest and vice versâ. The period is half a lunar year [$=9\frac{1}{4}$ solar years].

1870.

A. (*B.* 1.)

(*Page* 600.) The spots [of the sun] are only one of the known evidences of changeful activity going on in the great central luminary. The form, disposition and dimensions of the prominences, and the distribution of chromosphere are visibly undergoing constant alteration. May these phenomena not also have their periods of recurrence? and may not they, equally with the spot outbreaks, stand in some relation to what formerly used to be considered purely terrestrial phenomena, namely, magnetism, electricity, humidity, temperature and rainfall? To carry the hypothesis one step further: If there is a physical relation between the solar changes and meteorological occurrences, and if the solar changes are subject to laws which cause them to recur in regular series, have we not in this arrangement a clue by means of which climatic variations may be studied with greatly increased effect?

Ansted, D. T. (*B.* 2.)

(*Page* 103.) Hills can never be safely neglected in reference to climatal questions. (*Page* 111) The difference [between low plains and plateaux] greatly affects climates. (*Page* 112) But it is only in large tracts of lands that plains and plateaux attain (*Page* 144) dimensions sufficiently extensive to influence climate. Changes of weather are very rapidly and distinctly indicated by the colours of the sea water. These may be due to the movements of minute animal organisms, or they may be produced by changes (*Page* 150) in the state of the atmosphere. The ocean stream currents are of great (*Page* 151) importance to climates. The great currents are those which chiefly affect (*Page* 287) climates [Climate then means temperature]. Climate is a very complex matter, and one dependent on a great variety of conditions. It includes the temperature of the air at various times and seasons, the range and variation of temperature, the force and direction of the winds that prevail, the liability to storms, the amount of humidity in the air at various seasons, the quantity of cloud, mist and rain, the distribution of rain and the varieties of electrical condition. These to some extent affect and depend on each other, but all may ultimately be traced to certain general causes connected with physical geography. Among such causes are: 1. The position of the station in latitude. 2. The size and figure of the land on which the station is situated, whether detached island, archipelago or continent. 3. The elevation of the station above sea. 4. The position of the land on which the station is placed with reference to the neighbouring land. 5. The position, distance, direction, magnitude and elevation of the nearest continent. 6. The nature, magnitude and direction of the nearest great marine current to (*Page* 291) the shores. The climate of the south hemisphere is marine and insular; that of the northern hemisphere continental. The former is extreme, the latter average. (*Page* 292) There are no means of generalizing in meteorology without abundant facts, (*Page* 294) and the facts are of no value unless the instruments be accurate. The (*Page* 298) pressure of the atmosphere is another element of climate. The vicinity of the ocean and the constant freshening of the air by intermixture with other air that has passed over a large extent of sea seems favourable to life, while the influence of a large tract of land seems unfavourable. Islands are therefore, *cœteris paribus*, more healthy than places far removed from the sea, although there is no doubt that some islands, especially in the tropics, where the decay of organic matter is extremely rapid,

are among the least healthy localities. Electric storms are generally regarded as leaving the atmosphere in a more healthy state than before the storm. So many matters combining to produce a certain kind of climate, it is clear that even in the same very small tract of land there may be differences in this respect. It would be difficult at present to say why these differences exist, but the fact is notorious. Climate is (*Page* 299) so affected by winds that the direction of a mountain chain scarcely visible on the horizon, the position of a large tract of distant lowland, the presence at special seasons of icebergs floating in a sea a thousand miles away, or the fact of a current of water crossing, by a marine current, some great ocean that washes the shores—these are the simple elements from which the general climate of a country may be deduced; while the level of the land, the course of a river, the range of a few low (*Page* 300) hills, will any of them be sufficient to produce a local modification sufficient to alter the details of climate and greatly affect health and vegetation. And if in the course of ages a change should take place in any of these elements by the alterations that are constantly being produced by great natural forces always at work on the earth, it is clear that the climate must undergo a corresponding modification. Thus the diversion of the Gulf Stream up the Mississippi valley would render Europe (*Page* 301) colder and drier. Changes of climate and changes of the earth's surface are simultaneous, and both have certainly been produced ever since the earth was subjected to those influences of air and water that seem to us to be essential to its very existence. (*Page* 302.) Climate may and does change by the influence of man and cultivation. Weather is the condition of the climate of any particular country or district. It varies from day to day in most parts of the temperate zones, but in the tropics and in some special, but limited, areas, it is constant, and may be entirely depended upon during (*Page* 303) the whole dry season. A fine day in a fine season involves a goodly variety of conditions. On such a day we have a bright sun, but the sun's heat is not scorching, nor its light glaring; the sky is clear, and the clouds, if any, are light and high, not streaky or in heavy cumbrous masses during the day, and towards evening they clear away leaving only a few that are rosy and pink at sunset. The colour of the sky is blue, but not too intense, and not extending quite to the horizon. Distant objects are visible, but not quite so sharply defined as to appear unusually near. The atmosphere is really heavy, as shown by a high state of the barometer; but to the feelings it is light and elastic. The air feels dry, but not harsh. The temperature is seasonable. There is a motion in the air, but not enough to be called wind. It proceeds from a quarter generally favourable for fine weather in the place of observation. The electricity of the air is in a state of equilibrium. There is a fair supply of ozone, and there is no disturbance of the magnetic force. An average number of such days, occurring at intervals separated by cloudy and rainy weather of no long duration and not accompanied by violent and continued wind, electric or magnetic storm, or sudden and frequent changes in the temperature and pressure of the air, characterize a fine season; and several fine seasons following each other produce a cycle or period of fine weather. A certain amount of electric storm and hail in summer, intervals of heavy rain, wind and storm near the vernal and autumnal equinoxes, and an average of snow, frost and magnetic storms in winter are by no means incompatible with fine seasons. Bad weather and bad seasons are the opposite of fine. They also recur occasionally in (*Page* 304) cycles and alternate with fine weather and fine seasons. The general average of the weather represents the climate of the district, and in this sense it may be said that hardly any two places a few miles apart have precisely the same climate. In a general sense, however, the climate of England is spoken of as one thing, that of France as another, and so on. It is quite conceivable, and even probable, that the climate of a place may, in the course of a comparatively short time, undergo a change, although it takes a large number of observations to prove it. But though climate may change we may almost assert it as an axiom, in most parts of the world in temperate

latitudes, that the weather must change. There are places where these changes are excessively small, but we may safely assert, in a general sense, that weather is changeable and climate uniform. Climates are different in different places, whereas the weather, though changeable in any one place, may be the same at the same time in many places. The weather is often extremely different on the two sides of a mountain chain, across a narrow channel occupied by water, even in two localities on land a few miles distant from each other. It follows that while there are causes which influence weather of exceedingly wide operation, there are others altogether local. The prog- (*Page* 305) nostication and causes of change of weather must evidently be studied with reference to this important difference. There is a third condition of weather when, as in the case of storms, it travels over land and sea at a nearly even pace, occupying and affecting a narrow belt. During cyclones the weather travels in this manner. The signs and causes of this travelling weather are somewhat different from those of the other two kinds. The weather is essentially the state of the air at the place and time of observation, and change of weather involves the action of some external cause altering the condition of the atmosphere. The pressure of the air is constantly varying from a multitude of influences. The temperature of the air also changes every hour of the day. The moisture of the air varies with the temperature. The electrical state varies from many causes. The direction of the wind frequently changes. There is thus a great complication of phenomena. By observation of the external world or by (*Page* 306) combining these with notices of the habits and instincts of animals, any one may acquire an almost instinctive perception of weather-changes. The state of the air is one of the first things that may be studied with reference to the weather. There is hardly a more certain prognostication of coming change than an unusual clearness of distant objects. Generally in all temperate climates it is followed by bad weather within twenty-four hours, or if continued for some days, severe weather is almost inevitably at hand. The quantity, mode of arrangement, and form of clouds are all matters greatly to be looked at if we would foretell the weather a little in advance. Very light, lofty clouds, but detached from each other, and often crossing each other's directions, are frequently the first signs of change and coming wind after continued fine weather. These cirrus clouds are called cats' tails, and the sky covered with such clouds a mackerel sky: in summer they announce rain, in winter thaw. By degrees the clouds descend and become more prominent; they pass either into heaped masses of cumulus or into dense horizontal stratus, forming at sunset and disappearing at sunrise. Both kinds pass into grey, formless, leaden clouds, which (*Page* 307) at last empty themselves in rain. A very sudden alteration of form or shifting of the place of clouds, or a sudden obscuration of the sky without clouds in motion, is an indication of a state of the air generally belonging to changeable weather. When the round, heaped clouds appear early in the morning, they often gradually disappear as the day advances, and after noon the sky is clear; but when they come on after noon and increase during evening, obscuring the sunset, they generally terminate in rain. Any violent and rapid motion amongst the clouds, owing to various currents of air at different altitudes, indicates the approach of changeable weather. At a few thousand feet above the earth there is a cloud stratum which forms a kind of dividing plane, and the more immediate changes of weather no doubt commence there, while the more distant alterations require a longer time to perfect. A fine sunset is a valuable indication of the weather of the succeeding day. It requires, however, some experience to appreciate the exact state of the clouds in this respect, and the probability of interference by changes of wind or temperature. Among signs of fine weather an early and heavy dew has often been noticed. Hail in summer is generally preceded by great heat and followed by cold weather. The state of the air in which smoke rises vertically and to a considerable height is known to be frequently followed by fair weather, whilst the opposite state, in which the smoke is beaten down and refuses to rise, is unfavourable.

The direction of the wind and the direction of the change when the wind veers round are among the most valuable indications of weather open to the general observer. The (*Page* 308) latter is the more important as a prognosticating sign. A large amount of weather news is obtained by watching the animals and the conditions of vegetation, such as the flight of birds and insects, the departure of fishes from their usual haunts, the movements of cows and sheep in the fields, or of domestic animals in the house. Amongst human indicators are the martyrs to rheumatism and neuralgia, persons who have old and imperfectly healed wounds, those with dry consumptive coughs, or those (*Page* 309) who suffer from bronchial irritation. All the conditions of the air are the result of causes which, if clearly understood in their relative importance and mode of action, would be reducible to direct observation and calculation. They depend on the pressure of the air, the temperature of the air at the surface and at various heights, the dew point, the rainfall, the clear or cloudy state of the upper air, the direction and force of the wind, the electrical state of the air, the presence or absence of ozone, and the (*Page* 310) magnetic condition of the earth and atmosphere. A temperature continued for some time below or above the average is an almost certain indication of change. The direction of the wind and the agreement or disagreement of the direction with the average of many years at the same period or season is an important observation. When (*Page* 311) the wind veers the change may be looked on as not unfavourable, but when it backs bad weather may be expected to follow. Settled north-west wind brings cold and fine weather. Auroras are often followed in our latitudes by bad weather, but the precise relations of magnetic disturbance with weather changes are not yet fully understood. Peculiarities of weather, however great and strongly marked, must not, even when they extend over many years, be assumed to indicate permanent changes of climate. Although we may not be able to foretell the exact year of change, the general fact of periodicity of weather is clearly established. The power of foretelling is by no means easy to acquire; it can only be acquired by careful and frequent observations of the barometer and other instruments. It will also appear that, to judge of the weather a week in advance by noticing the hour at which the moon becomes new or full, or by observing the weather at such hour, can only be a very vague and uncertain method subject to various causes of local interference. It is not that valuable suggestions may not be obtained by collecting rules based on these suppositions. All observations and all modes of connecting observations have a certain value, as they may suggest the true explanation, even if they do not give it. But the problem is so complicated that no simple solution can suffice. The prognostications of the weather-wise sailor or shepherd are the result of the life-long observation of small signs, of the nature of many of which he is hardly aware himself, and which combine all that a dozen instruments, and as many careful meteorologists, can discover. Exactly in proportion to the experience and habit of close observation of natural appearances is the value of such an opinion; and this is all that can be said for the meteorologist's also, for he compares the experience of a large number of persons, and combines their results before he is justified in expressing an opinion; and his conclusion must fail should he neglect some correction which, however small, may largely influence the result. We may almost recognize the reality of an existence unhampered by material impediments when we find an instantaneous response of our innermost senses and sensations to a material stimulus applied within the burning atmosphere of the sun. Who has not felt the influence of weather in clearing up or obscuring the intellectual faculties? We attribute this to an indirect action through the state of our health; but who can say how much of it may not be due to some direct action proceeding from the sun? Perhaps some of those peculiarities of high nervous organization really owe their origin to a more ready sensibility to natural forces. The tendency of all observations on climates is to show that it is subject to a number of periodic changes, and we are fully justified in believing not only that the periods are many, but that we are by no means acquainted with all. A few years

reproduce some phenomena; others do not recur for centuries or even thousands of years. Geologists infer from observations that weather in special localities as well as climate must have varied greatly during different periods of the earth's history.

Somerville, M. (*B.* 43.)

(*Page* 33.) Plants and animals vary with climate. The phenomena of the atmos- (*Page* 308) phere depend upon the revolution and rotation of the globe, which successively exposes all parts of it and the air which surrounds it to a perpetual variation of the gravitating force of the two great luminaries, and to annual and diurnal vicissitudes of solar heat. Atmospheric phenomena are consequently periodical and connected with one another, and their harmony and the regularity of the laws which govern them become more evident in proportion as the mean values of their vicissitudes are determined from simultaneous observations made over widely extended tracts of the globe. The fickleness of the weather is proverbial, but as nearly the same amount of heat is (*Page* 309) annually received from the sun, and annually radiated into space, it follows that all climates on the earth are stable; and that their changes, like the perturbations of the planets, are limited and accomplished in fixed cycles, whose periods are still in many instances unknown. It is possible, however, that the air may be affected by secular variations of temperature during the progress of the solar system through space, or from periodical changes in the sun's light and heat. The spots on the sun must occasion periodical variations both in the light and heat of the sun. Accuracy in meteorological (*Page* 313) statements can only be obtained by means of averages of large numbers (*Page* 316) of observations. Observations tend to prove that all the climates on the earth are stable, and have remained so from the remotest historical periods, and that (*Page* 319) their vicissitudes are only oscillations of greater or less extent, which vanish in the mean annual temperature of a sufficient number of years. ['Climates' here is (*Page* 338) apparently restricted to temperature.] The atmosphere is much more unstable in the north hemisphere, with its excess of land, than in the southern, with its excess of water. Rains, fogs, thunder, calms and storms, all occur much more frequently, and are much more irregular as to time and place, on this side than they are on the other (*Page* 343) side of the equator. In the region of the trade winds the weather is steady (*Page* 386) and delightful. As the land rose at different periods above the ocean, each part, as it emerged from the waves, was probably clothed with vegetation and peopled with animals suited to its position and climate. And as the position and climate were different at each succeeding geological epoch, so each portion of the land, as it emerged from the ocean, would be characterized by its own vegetation and animals. The plants (*Page* 425) essential to man have great powers of adaptation to climates, especially the (*Page* 441) cerealia. The marine faunas are distributed in nine belts which surround the globe, each of which, being under nearly the same circumstances as to climate, has in its different parts either the same or representative species, and therefore it is said to be (*Page* 442) homoiozoic. The intertropical ocean forms the central homoiozoic belt; it has four others on each side, of which those at equal distances north and south have faunas mutually representative; the two last belts are the circumpolar oceans. The lines which bound the homoiozoic belts are climatal and nearly correspond with the isothermal lines on land, so that they are neither parallel to one another nor do they coincide with the parallels of latitude, but are undulating from the effects of the warm (*Page* 490) and cold currents which come from the tropical and polar oceans. Most animals [=mammals] perish from change of climate, and many must have inherited (*Page* 491) their present stations from the first appearance of the land. In the temperate zone of Asia and Europe there are such varieties in size and colour as might be expected to arise from differences of food and climate. In the inter-tropical regions and still more in the south temperate zones, the vertebrated animals are different, but in the similar climates tribes of forms in many respects analogous replace one another.

(*Page* 493) Many wild animals adapt themselves to change of climate; after some generations their habits and organizations alter to suit the new conditions. By draining (*Page* 526) marshes, cutting canals, making roads, turning the courses of rivers, opening communications, clearing away forests in one country and planting them in another man has altered the climate.

1871.

Maury, T. B. (*B.* 24.)

(*Page* 390.) To give forewarnings of approaching tempests on the coasts of the Adriatic, the Italian and old Roman castles had on their bastions pointed rods, to which as they passed the guards on duty presented the iron points of their halberts, and whenever they perceived an electric spark they rang an alarm-bell, to warn the fishermen and farmers of the approaching storm. This Italian custom was widely spread over the earth in former ages. In November 1854, the Anglo-French fleet was warned of an approaching cyclone. The fleet withdrew, and the storm broke over Sebastopol at the time predicted. The first idea of making use of the telegraph for conveying information as to weather occurred to Professor Henry in 1847, and he suggested it in the Smithsonian Report, published January 6, 1848, and it was further referred to in the Reports for 1848 and 1849, and subsequently, but it was not till 1856 that observations were actually collected and posted. It was in full operation in 1858, when weather maps were made from reports received at 10 A.M. America (*Page* 391) has the credit of first initiating and carrying into successful operation the systematic use of the telegraph for the simultaneous registers of the weather over large (*Page* 414) areas. The Signal Office of Washington estimated that the probabilities published were fully verified 50 per cent.; partly, 25 per cent.; while 25 per cent. failed. Many failures were due to lack of information from places without observers. (*Pages* 430–432.) Describes G. W. Hough's self-recording barometer and meteorograph. (*Page* 432.) Describes Wild's self-registering barometer.

R., W. (*B.* 39.)

(*Page* 466.) A meteorograph similar to Hough's, and invented by a Swede, was exhibited in the London International Exhibition of 1871.

1872.

Hall, J. J. (*B.* 17.)

(*Page* 327–8.) [The Swedish instrument exhibited in the International Exhibition of 1871 was Theorell's printing meteorograph.]

Howorth, H. H. (*B.* 21.)

(*Page* 24.) The increase of land round the poles in recent times must have influenced climates; it would materially alter the mean climate of both hemispheres. [Here climate seems to mean temperature solely or more particularly.]

Lockyer, J. N. (*B.* 25.)

(*Page* 98.) He dwells upon the millions of observations made in the British Isles, and remarks that the enquirers of some centuries hence will give up their examination in despair. In meteorology the thing to hunt down is a cycle; if no cycle can be found, plant the science firmly on a physical basis, and wait for results. Observation in the absence of method is for research purposes of very inferior value. Mr. Ferguson told me that every one in Ceylon recognized a 13-year cycle. I suggested the cycle might be 11 years. This conversation led to a letter in the 'Ceylon Observer,' which stated

that the weather cycle was 11-yearly; but not with mathematical regularity, for at one time it may be 13 years, and at another 11; giving a grand cycle of 30 or 33 years.

Murphy, J. J. (*B.* 40.)

(*Page* 142.) I do not think the most important question in meteorology is the discovery of a cycle; the chief desideratum is a dynamical theory of barometric waves.

P., H. (*B.* 41.)

(*Page* 420.) Prince says few prognostics of seasons can be relied on.

Scott, R. H., and Wm. Galloway. (*B.* 49.)

(*Page* 504.) They made curves based on the records at Stonyhurst; 30 per cent. of the colliery explosions were unaccounted for on meteorological grounds. They conclude that meteorological changes are the cause of most of the explosions; 48 per cent. were attributed to the state of the barometer, and 22 per cent. to the state of the thermometer.

1873.

Barrett, W. F. (*B.* 1.)

(*Page* 23.) One important feature of the translation of Flammarion's 'Atmosphere' is the frequent graphic delineation of data.

Flammarion, C. (*B.* 13.)

(*Page* xi.) As it exists at the present day meteorology is a new science of recent establishment, scarcely as yet fixed in its elementary principles. The present generation has seen the establishment of meteorological societies throughout the different nations of Europe, and of special observatories for the exclusive study of problems relating to the atmosphere. The analysis of climates, seasons, and periodical phenomena, is scarcely terminated. The science of the atmosphere is the question of the day. Meteorology will be founded in the nineteenth century. The work is intended to collect all that is (*Page* 9) positively known on the subject. The solar heat keeps in continual work the mighty factory of the terrestrial atmosphere, organizing the permanent system of the (*Page* 45) vital circulation of the globe. Solar heat gives rise to regular diurnal and monthly variations, the intensity of which differs according to the latitude. It now (*Page* 200) becomes necessary to ascertain what part of the immense calorific radiation which is incessantly emanating from the sun is at work in the atmosphere. Meteorology is nothing but a great physical problem. We have to determine what are the laws which regulate the manner in which heat, barometrical pressure, vapour of water, and electricity, are distributed in our atmosphere in relation to the movements which the solar heat engenders in the solid, liquid, and gaseous superficial stratum of our globe. This problem, as Father Secchi says, is in reality but an application of the best known laws of physics; the difficulties of solving it are owing rather to the large number of disturbing causes, and to the incalculable reactions of effects upon causes, than to any real deficiency in the general theory. Hence the necessity of numerous experimental data in order to arrive at a complete solution.

Maury, J. B. (*B.* 26.)

(*Page* 124.) Meteorologists say the science is as old as Aristotle; but its progress has been very slow up to the middle of the present century. Within the past few years it has rapidly developed.

Stevenson, T. D. (*B.* 56.)

(*Page* 103.) The elements of time and distance should form part of the meteorological records. The gradient of all the elements should be calculated. There should also be horizontal sections by means of instruments placed at short distances from each other, and also vertical sections. The latter could be effected by having a series of stations on the slopes of a mountain.

Nature. (*B.* 64.)

(*Page* 341.) Even under the present diverse systems of observation much valuable material has been accumulated; but its value depends only on its being sufficiently approximate to meet the requirements of some of the more pressing questions, not because it is precise. Where questions require precision and uniformity the present systems of observations are found to be sadly wanting and unsatisfactory. Uniformity is much to be desired. The conference [at Leipzig in 1872] was only a consultative one, preliminary to one proposed for 1874 in Vienna. Twenty-six questions were proposed. (*Page* 342.) It was recommended that aneroids should not be substituted for the mercurial barometer.

Nature. (*B.* 65.)

(*Page* 468–469.) [Gives a programme of the subjects discussed at the Vienna Congress. It consists of 28 questions.]

Nature. (*B.* 67.)

(*Page* 335.) Professor Chase (Am. Phil. Soc. Philad., July 19, 1872) read a paper on 'Æthereal oscillation: the primordial force,' and stated that certain meteorological observations had been verified which had been based on his observations of the rainfall at San Francisco.

(*Page* 455.) R. H. Scott (Meteorol. Soc., March 19), read a paper 'On Some Results of Weather Telegraphy.' The information received was insufficient, both as regards quality and quantity, to give a complete idea of the weather. Serious results arise from the frequency of telegraphic errors.

Nature. (*B.* 70.)

(*Page* 484.) During the year the Signal Service of the United States sent out 187,617 bulletins and 203,533 maps. The forecasts up to November 1, 1871, were verified to the extent of 69 per cent; since that and up to October 1, 1872, to 76·8 per cent. The precautionary signals were verified to the extent of 70 per cent.

1875.

Hopkinson, John. (*B.* 4*.)

(*Page* 34.) Observations of the periodical phenomena of plants and animals alone may furnish climatological data of importance in the operations of the farmer and gardener. Combined with meteorological observations they may afford valuable assist-(*Page* 35) ance in investigations on climate, for these periodical phenomena both of plants and animals are all more or less regulated by the laws of climate, and the varying influences of the seasons. It is here that union is required. As an example of the information that may be derived from these naturalists' calendars it may be mentioned that by comparing the various records of similar observations made simultaneously upon the species selected at a number of stations in this and other countries, we may distinguish those localities at which the same phenomena occur at the same time, and by drawing lines through these localities we may indicate with clearness the isochronism of the phenomena and therefore of the climatal conditions on which they are dependent.

Sayce, A. H. (*Nature*, xii.)

(*Page* 489.) The 'Observations of Bel' were compiled before B.C. 1700. This treatise shows that amongst the Accadians cycles of 12 solar years were in use, during which the same weather was expected to recur.

Stewart, Balfour. (*B.* 42.)

(*Page* 348.) Terrestrial meteorology baffles us owing to the largeness of the scale and (*Page* 350) the isolation of the observers. An exhaustive catalogue of all that has been done in meteorology in the English dominions has been framed by a British Association Committee. It requires to be supplemented by all that has been done abroad.

Nature. (*B.* 52.)

(*Vol.* xii. *Page* 160.) (Acad. Sci. Paris, June 14.) Fautrat read a paper 'On the (*Page* 264) influence of forests on climate,' etc.—(Acad. Sci. Paris, July 19.) On (*Page* 405) Espy's meteorological essays by M. Faye.—(Brit. Assoc. Meeting, 1875.) Dr. Hennessy read a paper 'On the influence of the physical properties of water on (*Page* 488) climate.' [It refers to temperature.]—Zeits. f. Meteor., August 15, describes Theorell's printing meteorograph.

(*Vol.* xiii. *Page* 56.) (Germ. Sci. Assoc. Meeting, 1875.) Method of representing (*Page* 140) the various constituents of weather in a short and compact manner, by Dr. Prestel.—(Acad. Sci. Paris, December 6.) Atmospheric perturbations of the hot (*Page* 160) season of 1875, by M. Belgrand.—(Acad. Sci. Paris, December 13.) Atmospheric perturbations of the hot season, by M. Belgrand. Meteorological observations in a balloon, November 29, by M. Tissandier.

1876.

Evans, John. (*B.* 4.)

(*Page* 115.) [Refers to meteorological instruments: but has no remarks worth noting connected with climate.]

Spes. (*B.* 12.)

(*Pages* 169, 170.) [Suggests that meteorology be treated as a distinct science by having professoriates of meteorology.]

Symons, G. J. (*B.* 15.)

(*Page* 10.) [Simply a notice that the thermometers established under the auspices of the Meteorological Society are all placed as nearly as possible 4 feet from the ground.]

Nature. (*B.* 17.)

(*Page* 107.) The 'New York Herald' of November 7, publishes a map of the weather of the morning, exhibiting the lines of atmospheric pressure and of the temperature of the United States. The meteorological charting, which was finished at the Central Office in Washington at 10 A.M., was immediately transmitted from Washington in facsimile by telegraph to Philadelphia, where it was received at 10·30 A.M. It was shortly thereafter published in the supplement of the 'New York Herald' of the same day, being the first occasion on which such telegraphing charting had appeared in any newspaper. The fact of telegraphing and printing such charts solves one of the greatest difficulties of exchanges of weather reports. It may now be regarded as only a question of time when the more important newspapers of our British large towns will be in a position to present their readers every morning with a chart of the weather as existing only two or three hours before going to press; and, indeed, it will not be till this result is effected that the practical utility of weather warnings will be properly developed,

owing to our close proximity to the Atlantic, and the rate at which our weather changes pass to the eastward.

Nature. (*B.* 19.)

(*Page* 10–11.) [Account of meeting of the Vienna Meteorological Congress. Notice of resolutions made.]

Nature. (*B.* 21.)

(*Vol.* xiii. *Page* 218.) (Zeits. f. Meteor. Nov. 15.) Wild reviews the work of the Meteorological Congresses of 1873 and 1874. Reprinted from the Annual Report of the (*Page* 440) Imp. Obs. at St. Petersburg.—(Meteor. Soc., March 15.) On the deduction of mean results from meteorological observations by L. F. Kämtz, trans. from Repert. f. (*Page* 497) Meteor. by J. S. Harding.—(Zeits. f. Meteorol., Dec. 1, 1875.) Wild on the Congresses. The sole result of these it had been urged would be to pile a million useless figures upon a million others already published. Wild admits that comparatively few of the figures are of any use; but who is to decide which will or will not be serviceable? Observations are faulty owing to their deficiencies, inconvenience of form, or variety of arrangement. Published observations are more carefully revised than unpublished. The (*Page* 491) latter are for the most part useless.

(*Vol.* xiv. *Page* 143.) (Meteor. Soc., May 17.) Remarks on the present condition of maritime meteorology from 1853. Loomis's Contributions to Meteorology, 5th (*Page* 420) paper. Am. Journ. Sci., July 1876. The 'Bothkamper Beobachtungen,' No. 3, contains Lohse's meteorological observations in the year 1873. Montigny (*Page* 562) (Bull. Acad. Roy. de Belgique, 1876, No. 8) has an elaborate report upon the connection between scintillation and various meteorological elements.

1877.

Abercromby, Hon. R. (*B.* 1.)

(*Page* 510.) Meteorology is said not to be a science by Airy, Sir Wm. Thomson, and others; but a great change has come over the whole aspect of meteorology since the introduction of synoptic charts. Synoptic meteorology shows that the world is covered with shifting cyclones and anticyclones, which have each, subject to local, diurnal, and other variations, a characteristic weather and physical appearance; and one great problem of meteorology is to explain the observed weather over any area at any instant by defining the position of these cyclones and anticyclones. It is also said that the knowledge requisite to issue forecasts cannot be expressed in mathematical formulæ or in simple maxims. Mean values or harmonic series will never advance meteorology much as a science. Meteorology is as much a science as geology.

Broun, J. A. (*B.* 2.)

(*Page* 251.) Strachey's true criterion of a periodicity is this. If the differences of the rainfall [the rainfall of Madras is meant, but the remarks apply generally to climate] for each year from the mean of the whole 64 years be taken, and the mean of all these differences (without respect to sign) be called the general mean difference; if we average the yearly rainfall in horizontal series of 11 successive years, and the means for the first, second . . . years be taken, these quantities (periodic means) will show the mean variation in the period of 11 years, if any such exist. If now the differences of the yearly rainfall from the periodic mean for the corresponding years be taken, the means of these, irrespective of sign, may be called the periodic mean difference. His true criterion appears to be that if there be no periodicity the variation in the periodic means will tend to disappear in a sufficiently long series of observations, and the general and periodic mean differences be identical. It seems to me that the disappearance of a

variation in the periodic means is here the true criterion of no periodicity. Strachey (*Page* 252) concludes that when the periodic mean difference is much less than the general mean difference, a true period exists. I will show that this is no criterion of periodicity. If we represent variations of any quantity for a given time by a curved line, and if we have several such lines of exactly the same form placed one over the other, a straight line passing through the curves, with as much space between the straight and curved lines above as below, will represent the general mean. In a simple curve of two branches, the general mean difference will be nearly one-fourth of the amplitude of the oscillation; while as all the oscillations agree with each other, and therefore with the mean oscillation, the periodic mean difference will be zero. If, however, we displace the individual curves so that as many shall be above as below their mean, both the general and the periodic mean differences will increase, and the differences between these quantities will diminish till the individual curves are so separated from the mean that none of them is cut by it, when the two mean differences will be equal; between this case and that of general coincidence the two mean differences will have values which will differ more or less from each, according as the individual curves are nearer to or more remote from the mean; and the ratio of the one mean difference to the other will tend to a constant value as the number of cycles increases, a ratio which will depend for its value on the mode of distribution of the individual curves and of the irregular deviations from the mean. The two-hourly observations of the barometer at Simla for six days in Jan. 1845, gave as follows: general mean difference, ·0634 in.; periodic ditto, ·0615 in. Or if the first five days be taken, we get: general mean difference, ·0656 in.; periodic ditto, ·0634. Here we have a large and regular semi-diurnal period where the periodic is not one-thirtieth less than the general mean difference.

Buchan, A. (*B.* 3.—*The reference should be to vol.* xvi., *not* xvii.)

(*Page* 424.) Meteorologists have for some time been aware that the 11 years cycle of sun-spots is coincident with a cycle of atmospheric conditions producing ascertained terrestrial effects.

Hunter, W. W. (*B.* 8.)

(*Page* 455.) The cyclic coincidence may be tested thus. If it really exists there should be a well-marked minimum group at the extremities of the cycle (in the 11th, 1st, and 2nd years), and a well-marked maximum group in the middle (the 5th and the following years). The years on both sides of the central maximum group should yield intermediate results, and when taken together should form an equally well-marked intermediate group.

Kinahan, J. H. (*B.* 9.)

(*Page* 334.) [Nothing for general notes.]

Stevenson, Thomas. (*B.* 21.)

(*Page* 586.) Prof. Balfour Stewart has separated meteorology into two great divisions —physical and climatic. The latter I have proposed to separate into two subdivisions, viz. normal and abnormal. The first of these subordinate branches includes the investigation of the usual states of the atmosphere in different parts of the earth's surface, as ascertained by periodic data derived from the averages of observations continued for a series of years. The second subordinate branch has for its object the investigation of unusual temporary disturbances of the equilibrium of the atmosphere, such, for example, as storms of wind, by means of the comparison of individual observations extending over only a few hours or a few days. Physicists of high standing look with disfavour on meteorology, owing to the want of agreement amongst meteorologists as to the means of determining even the most important fundamental data. One essential condition is uniformity in instrumental observations. No uniform inter-

national system has been established. Glaisher has induced many observers to adopt the uniform height of 4 feet above the ground for thermometers and an uniform screen. The Scottish Meteorological Society has adopted the height of 4 feet, and my double louvre protecting box. The Meteorological Society of England has adopted the same uniformity of boxes, their exposure and hours of observation; but amongst observers generally and on the Continent there is less approximation to uniformity. Without uniformity the results obtained are not comparable. Climates may be defined as states of the atmosphere due to the joint operation of geographical, geological, and other conditions more or less local, and they are judged of by their effects on animal and vegetable life. They do not depend, therefore, simply on the geographical position on the earth's surface of the district where observations are made, but are largely affected by various conditions, such as the distribution of land and water, the nature of the soil and its covering, and the elevation or depression and character of the land at or adjacent to the place. Climates are therefore frequently of a local nature, that is, of small superficial extent. Thus many varieties of climate may co-exist about the same parallel of latitude, and even over a very limited portion of that zone. That such local atmospheric distinctions do exist is shown by the varied distribution of plant-life, which, though no doubt largely affected by the nature of the soil, is nevertheless dependent to a considerable extent on the existence of certain atmospherical conditions.

Stewart, Balfour. (*B.* 22.)

(*Page* 45.) Dr. Arthur Schuster has found that the years of minimum sun spots (*Page* 46) coincide very nearly with the good wine years in Germany. The temperature ranges at Kew have an apparent reference to the sun; the ranges being greater at times of maximum sun-spot frequency, but the correspondence is not so great as in the case of the magnetic disturbance. Do these fluctuations occur simultaneously with the solar fluctuations? or do the solar fluctuations occur first? in the latter case we could predict the greater meteorological occurrences. The Kew observations seem to indicate that the temperature fluctuations occur six months after the solar. Meteorologists are beginning to suspect a somewhat intimate connection between the magnetism and the meteorology of the earth. Baxendell, I think, first pointed out that there is a diurnal inequality in the direction and velocity of the wind apparently connected with the daily changes of magnetic variation. J. A. Broun says that meteorological phenomena are due to solar action; the heating action is one, but there also seems to be a second which introduces forces we cannot at present appreciate. If the sun affects (*Page* 47) the earth, so also may the moon. It certainly influences the earth's magnetism, and Mr. Park Harrison has pointed out that its temperature is influenced by the relative position of the sun and moon. I have noticed an unmistakable reference to the phase of the moon in the daily temperature range at Kew. In the summer, when the full moon is low in the heavens, we have a less decided reference, which seems to imply a maximum of daily temperature range about new moon and also about full moon. But in winter, when the full moon is high, we have a very decided reference, showing a maximum of daily temperature range about new moon and a minimum about full moon. The same features occur in the magnetic ranges. He suggests that, as solar research, terrestrial magnetism, and meteorology hang closely together, they should be studied together.

Stewart, Balfour. (*B.* 23.)

(*Page* 161.) The true test of a physical cycle is its repetition.

Nature. (*B.* 26, 32.)

(*Page* 59.) Dr. Williams treats the subject to which his book relates in its climatic relations, and gives a discussion of the data adduced with regard to the therapeutical

action of British, Mediterranean, African, Indian, Australian sea voyages and other climates differing widely from each other as regards temperature, humidity, elevation, and exposure to sudden changes of weather.

Nature. (*B.* 31.)

(*Page* 263.) Prof. Fritz finds evidence of an 11-yearly period in the hail-storms (*Page* 458) and high river floods. Prospects of fair weather are increased in pro- (*Page* 460) portion to the elevation of clouds. The 'New York Herald' has sent seven storm-warnings since the end of February.

Nature. (*B.* 32.)

(*Page* 171.) (Royal Soc., May 24.) General Strachey 'On the alleged Correspondence of the rainfall in Madras with the sun-spot period and on the true criterion of periodicity in a series of variable quantities.' The only signification of the arithmetical mean value of a series of observed quantities is, that it is one above and below which there is an equal amount of deviation in the individual observations. The question is whether the mean values thus obtained can be accepted as showing a definite law of variation from year to year in the cycle. In the case of the Madras rainfall it seemed to make little difference whether the cycle adopted be 11 years (*Page* 172) or 4, 5, 6, 7, 8, 9, 10, 12, and 14 years. Now, if in any series of quantities there be a law of periodicity, each observed quantity may be supposed to be compounded of a periodical and non-periodical element. If we take the sum of a large number of cycles, each of which coincides with the cycle of periodicity, the non-periodical elements will tend to be eliminated and the means for the successive years of the cycle will indicate the periodical elements for the successive intervals. At the same time the differences of these means from the several original quantities from which they were obtained will be the several non-periodical elements. In proportion as the periodical elements are large or small in relation to the corresponding non-periodical elements, so the difference (obtained as above) will be universally less or more different from the differences between the individual observations and the mean of the whole of them; and if there be no periodioity the two sets of differences would, in a sufficiently long series, be identical. Hence it may be inferred when the differences (taken as before) closely approximate in magnitude to the mean difference of the original observations from the arithmetical mean of all of them, the periodical elements in these observations must be correspondingly small. The mere circumstance of any series of cyclical means showing a single maximum and a single minimum gives no real indication of such a result being a truly periodical feature. The test of the periodicity is to be sought altogether outside of the particular values of the successive elements of the cyclical means. It is manifest that a complication of periodical elements may so mask one another as to prevent positive results being obtained by the examination of the means and differences. (B. 39.) The new (*Page* 224) Meteorological Council of the Royal Society has no meteorologist on it. [The article is on the constitution of the Council and the disposal of the funds.] (*Page* 253.) General Strachey contends that a periodicity is not indicated unless the general and periodic mean differences differ by at least 10 per cent. The periodicity represented by the diurnal barometric oscillations at Madras is too simple a test for the new criterion; it should be tested on such a curve as the barometric oscillations at Valentia for December 1876, which, however, gives a difference between the two means of only 1-10th per cent., and not rising to 1 per cent. for any of the 24 hours. The averages for the months, however, show most decidedly the presence of a periodicity. The phenomena of the diurnal oscillations of the barometer are among the most uni- (*Page* 254) versally accepted and best established periodicities of science. Were Strachey's new criterion accepted, it would sweep from our view scores of periodicities

now everywhere accepted and prevent enquiry in those departments, in which the non-periodical are very largely in excess of the periodical variations, of which meteorology may be regarded as presenting the most numerous and best illustrations.—(Brit. Assoc. (*Page* 375) Meeting.) Meldrum. The evidence in favour of a cycle has much increased. Confirmatory results have been obtained from the rainfalls at 13 stations in the (*Page* 452) French colonies from 1832 to 1872.—Alluard (Acad. Sci. Paris, Sept. 18) notices that frequently the barometer has risen at Clermont while falling at Puy de Dôme. This shows the necessity of studying the atmosphere in vertical layers.

Nature. (*B.* 33.)

(*Page* 113.) Dr. Warring (Amer. Journ. Sci., Nov.) discusses the question, Is the existence of growth-rings in the early exogenous plants proof of alternating seasons? Some exogens form rings at intervals much less than a year; others require several years; and some form no rings. The presence or absence of rings in exogens occurs in all climates. Large and well-defined rings are formed where there is absolutely no appreciable variation of temperature or moisture throughout the year. An exogen naturally forming rings will continue to form them although the climate become uniform throughout the year. Thus the existence of these markings in the ancient flora gives no information as to the existence at that time of seasons.

Nature. (*B.* 36.)

(*Page* 399.) [This is a reprint of the Report.] Meteorology at present stands in (*Page* 400) need of hypothesis and discussion at least as much as of observations.

Nature. (*B.* 37.)

(*Page* 51.) The British Meteorological Board have notified that the weather telegrams will be discontinued on Sundays during the summer. [This no doubt refers to the British Isles.]

Nature. (*B.* 39.)

[This is given under B. 32. See above.]

Nature. (*B.* 40.)

[Nothing in it for general notes.]

1878.

Abercromby, Hon. Ralph. *On the General Character and Principal Sources of Variation in the Weather at any part of a Cyclone or Anticyclone. Q. Journ. Meteorol. Soc.* IV. pp. 1-13. Published in No. for Jan.

(*Page* 1.) Two methods have to be combined to obtain a complete idea of cyclone or anticyclone weather. The first, or synoptic, method consists in drawing an isobaric map, and marking on it the position of rain, clouds, &c., by which their position relatively to each other and to the cyclone or anticyclone centres can be ascertained; in fact, in making a plan of the weather. The second method consists in recording the sequence of phenomena which occur to a single observer as a cyclone or anticyclone passes over him; in fact of drawing a section of the weather across a cyclone along a line parallel to its path. When this is done, it is found that the mere words rain, clouds, &c., such as alone can well be marked on a synoptic map, convey but a very (*Page* 2) imperfect idea of their character and surroundings, as the kind of rain and kind of cloud vary much in different parts of a cyclone, and are readily distinguished. Also that the passage of similar parts of different cyclones over an observer does not bring exactly the same weather; for in one cyclone the sky may be merely overcast, while in another there is heavy rain; and in one anticyclone there will be thick wet fog,

while in another dry winds and blue sky will prevail. These two methods, the plan and section as it were, are so widely different, that it is difficult practically to combine them, and to realise how a difference in a cyclone, on a synoptic map, will affect the sequence of weather as it passes over an observer. The object of the following paper is to define generally the nature and sphere of the principal sources of variation in the weather at each part of any cyclone or anticyclone, and to show how, in spite of endless diversities, certain broad characteristics of each are always maintained. Though the illustrations and details will refer almost exclusively to the weather of Great Britain, the general principles laid down appear to be of universal application in every part of the world. The first source of variation in any cyclone or anticyclone depends on the type of general distribution of pressure to which either belongs. The commonest type of cyclone in this country has the highest pressure some point south of the centre, on which side steep gradients are found, while on the north side the gradients are very slight. In this case the rain and cloud area extends far to the S. and S.E. of the centre, but comparatively little to the N. and N.W., while the hardest weather is generally found to the point of S., where the steepest gradients are. In another less common type the highest pressure is some point to the N.E. of the centre, on which side the steepest gradients are found, while to the S. and S.W. the gradients are slight. In this case the rain and cloud area is very differently shaped from that just described, extending farthest from the centre in the N.E. direction, and less in the S. or W., while the hardest or most severe weather is found to the point of N.E., where the steepest gradients are. If also we consider the position of strongest wind, or the direction of the wind relative to the isobars, or the distribution of temperature relative to the centre, we find that certain general features common to every cyclone undergo considerable modifications, according to the type of pressure distribution to which it belongs. The former of these two types particularly mentioned above may conveniently be called the westerly, and the latter the north-easterly type of cyclone. In anticyclones (*Page* 3) the influence of type is much less marked than in cyclones. The next source of variation is the difference of what may aptly be called the intensity of any cyclone. In cyclones of the same type the weather differs much in hardness or severity, or in quietness. Thus in the S.E. front the sky may be simply soft and overcast in a cyclone of moderate intensity; but with increased intensity the overcast sky would develope into soft drizzling rain, or even into a peculiar class of thunder-storms; but, in spite of all these variations, there is always the close muggy atmosphere and dirty sky characteristic of this part of a cyclone. Again, in the rear, the general character is always a cool, brisk feeling in the air, with a bright and broken sky, which varies according to the intensity, from simply heavy masses of cloud to hard showers, to squalls, or to hail-squalls, with thunder and lightning; but no difference of intensity can ever alter the fundamental difference in the general character of the S.E. front and rear portions of a cyclone. It is well known that a deepening cyclone is increasing in intensity, while one which is filling up is decreasing. In anticyclones the term intensity is much less applicable to their characteristic weather than in cyclones. The term intensity has been applied by the Rev. W. C. Ley to the difference of weather due to the steepness of gradients, and though that is one, and perhaps the principal source, of variation in intensity, the term is capable of considerable extension of meaning. Short-lived cyclones, forming and disappearing rapidly, or a great development of secondaries, in which gradients are usually slight, though the weather, so far as rain and thunder are concerned, is very severe, are atmospheric conditions to which the term intensity is equally applicable. Another source of variation depends on the size and shape of the cyclone, and is intimately connected with type and intensity. It might obviously be expected that the weather in any part of a large cyclone as, for instance, one of those which sometimes entirely cover the Atlantic Ocean, would be very different from the weather in a small cyclone, which perhaps only just covered

the British Isles; and this is fully borne out by observation. In very large cyclones, the steepest gradients and the bad weather which accompanies them are always found at some distance from the centre. Round the centre itself, when the gradients are very slack, the sky is usually broken with hardish clouds, and there is a cold pleasant feeling of the air. In small cyclones the heaviest rain usually surrounds the centre, and extends more or less to one side or the other, according to the direction of the nearest area of high pressure and the steepest gradients. Another source of variation in the size and extent of a cyclone rain and cloud area has been pointed out by Professor Loomis. His examination of the United States' weather chart points to the conclusion that the rain and cloud area is extended farther in front of cyclones that are moving (*Page* 4) rapidly than in those moving slowly; but Mr. R. H. Scott has pointed out that it is difficult to trace this over an area so intersected by sea and land as the British Islands. Another great source of variation is a class of phenomena which has as yet no recognised name, but to which the term diurnal variation seems very applicable. To a single observer the broadest feature of the diurnal variation of the weather in a cyclone is that, starting from early morning, the amount of cloud and the general severity of the weather and rain gradually increase till about 2 P.M., and then gradually decrease till nightfall. Occasionally a type of cyclone occurs in which the rain comes on during the night and takes off or ceases during the day. This is undoubtedly due to some far-distant general causes affecting the origin of the cyclone; but the few cases I have been able to trace are not sufficient to form any opinion on the subject; a diurnal variation of the weather is, however, sufficiently well marked, though it is to a certain extent abnormal. (*Note.*—Diurnal variation is also much influenced by the type of pressure distribution. With north-west winds and pressure high to the S. W. of Great Britain cloudy days often culminate with a squall or shower about 4 P.M., and then subside to quiet nights.) In anti-cyclones the diurnal variation presents a marked contrast to that in cyclones. In them a misty or cloudy morning is followed by a great diminution of cloud as the day goes on, while later on in the evening mist and cloud are sometimes again formed. If, besides these broad features of diurnal variation, we consider some of its more minute changes, we observe that in cyclones a cloudy morning often has a short break about 10 A.M., that the weather then becomes much worse, but has a marked tendency to break again about 4 P.M. In anti-cyclones a clear morning at 4 A.M. is frequently very cloudy at 10 A.M., after which the cloud again decreases till about 4 P.M., when more cloud or mist is often again formed, and last till quite late in the evening. The increase of cloud during the day in cyclones may be generally described as an increase of intensity; the decrease of clouds in anti-cyclones is not so easily explained, unless it is due to the increased intensity of the descending current found in them; but the minor changes at 4 A.M., 10 A.M., and 4 P.M. are obviously connected with the normal variation of the barometer, and their attentive study may perhaps some day throw light upon that puzzling phenomenon. But whatever modification the diurnal variation may make in a cyclone or anti-cyclone the general character of either is never lost. No diurnal variation can make the clouds and look of weather in front of a cyclone like the clouds in the rear or like the clouds formed from rising mist in an anti-cyclone, the variation being not merely a modifying influence superimposed on a more general effect, but in some cases where the general character is not very strongly marked, the diurnal variation becomes an important feature in a day's weather. Hence, if we take the case of a stationary cyclone, and lay down on a synoptic chart the weather at any part of it, the extent of the cloud and rain areas will extend much farther from the centre at 2 P.M. than at 8 P.M., and in an anti-cyclone much cloud will be found near the centre at (*Page* 5) 10 A.M., but very little at 2 P.M. (*Note.*—Since writing the above I have seen a number of United States' tri-daily synoptic maps. In some of them the difference of cloud and wind in the same disturbance at different hours of the day is very well

marked.) Some diurnal variations of the weather seem to take place in every part of the world, as, for instance, the daily thunderstorms which occur in some parts of the tropics. The above details apply to the British Isles only [but still they have a general bearing]. Another very important modification in weather is local variation. It is well known that in any storm the position of showers, squalls, and thunderstorms is very local, and at some places, either from the contour of the ground or other causes, they are much more frequently developed than at others; so also with the amount of rain-fall, the position of ridges of hills relatively to the prevailing direction of the wind, or the presence of lakes and forests as compared with bare ground, or the position of the sea relatively to the prevailing wind, all seem to have an important influence in regulating its amount. So important is the position of the sea that on our east coasts the worst weather is with east winds, while on our south coasts it is worst with west winds. In anti-cyclones and under any conditions where easy gradients do not give any very general marked character to the weather, the local variation is much more important than in cyclones where the general character is much more strongly marked. Local variation is found in every part of the world; and in the tropical and equatorial regions, where barometric gradients are usually slight, it becomes a more important element of weather. The last source of modification, I would notice, is the seasonal variation. In this country during winter the cyclones are usually much larger than in summer, and even in cyclones of about the same size and intensity the position of the rain and cloud area is not quite the same. In winter time the clouds and general appearance of the sky are usually softer than in summer, and the rain is more drizzly and less showery, besides many other smaller differences, which are too well known to require minute description. We shall now describe the general pheunomena which appear to a single observer as different parts of a cyclone past over him, by which we acquire the knowledge of other important facts not to be deduced from synoptic maps. In a British cyclone of ordinary size the rain area and cloud ring are divided into three well-defined portions which differ much in general character, viz., the N.E. front, the S.E. front, and the W. or rear side. The front is divided from the rear by a line drawn through the centre of the cyclone, in front of which the barometer is falling while in rear it is rising. The passage of this line over an observer, especially its southern half, (*Page* 6) is marked by a very sudden and striking change in the appearance and feeling of the weather; the N.E. and S.E. fronts, though they have much in common, are sufficiently different to be classed separately, and are divided by the line drawn through the first, which represents the path of the cyclone; but this line does not mark the position of any great physical change, as the weather in either front merges gradually into the other. In the N.E. front, when the steepest gradients are somewhere south of the centre, the first symptoms of its approach are a gradual darkening of the sky till it becomes overcast, with very little of the appearance of the formation of true cloud; or else light wisps or barred stripes of cirrus, moving sideways, appear in the blue sky, and gradually soften into a uniform black sky; near the centre, light ill-defined showers fall from the uniformly black sky, the wind from some point between south-east and north-east blows uneasily, and though the air is cold and chilly there is an oppressive feel about it. These appearances continue till the barometer begins to rise, when the character of the weather at once begins to alter. In a cyclone where the steepest gradients are somewhere to the north and east of the centre, the general character of the weather is the same as above described, but is much more intense, the wind rising at times to a heavy gale and the ill-defined showers developing into violent squalls. In the south-east front, when the steepest gradients are to some point south of the centre, the first symptoms are likewise a gradual darkening of the sky into the well-known pale or watery sky, with a muggy oppressive air, or else, as in the N.E. front, wisps of cirrus first appear in a blue sky, which gradually become heavier and soften till the sky is uniformly overcast. Nearer the centre, rain, usually in the form of

drizzle, sets in, and the wind, from some point between south-east and south-west, varying in force according to the gradients, drives the cloud and rain before it. But this wind differs from that in the other portions of the cyclone in its way of blowing; and for the same velocity does not raise so high a sea, or seem to bear so much down on the surface of the earth. In cases of very great intensity, the rain in this portion of a cyclone may come in showers or even in squalls, but the general character is never lost. These characters last till the barometer begins to rise. A line drawn from the centre of a cyclone in that southerly direction, along which the barometer turns to rise, marks out the position of one of the most striking parts of a cyclone. Viewed on a synoptic chart a small secondary cyclone is often formed in some part of it, or else a curious V-shaped depression, which frequently extends to the south of the centre. It would be a point of very great importance to determine accurately how far the line along which the barometer turns to rise is at right angles to the direction of the path of the cyclone. As far as my own researches have gone it seems to be often at right angles to that motion, but frequently it stretches nearly due south of the centre, even when the cyclone is going well to the north of east. It is sometimes very difficult to draw this line accurately, owing to the frequent changes in the depth of any cyclone. As any portion of this line passes an observer, an immediate (*Page* 7) change comes over the whole appearance of the weather, and the transition is often accompanied either by a very heavy shower, squall, or hail, with a small irregular fluctuation of the barometer. The general character of the west or rear side, which now passes over the observer, is a cool, exhilarating feeling in the air, with a high, hard sky, of which the tendency is always to break into firm detached masses of cloud. The rain which occurs near the centre is usually in cold, sharp, brisk showers or hard squalls, and the general hard look of the weather presents a marked contrast to the dirty appearance of the weather which characterises the whole front of a cyclone. As the centre recedes from the observer, showers or squalls are replaced by simply detached masses of cloud, and these finally disappear, leaving a blue sky. The wind from some point between west and north blows gustily and for the same velocity raises a higher sea than a south-west wind, and seems to bear down more on the surface of the water. The whole of the rear of a cyclone partakes of this general character, but the change of weather along the line drawn north of the centre, along which the barometer turns to rise, is not nearly so strongly marked as along the southern line. In one of the few cases I have been able to observe of weather on the north side of a cyclone going west, the north-west wind, in what was then the front, was dull and oppressive, but when the wind veered to north-east the sky broke to cumulus and the air felt fresh. This seems to suggest the important conclusion that the specific characters of the front and rear are due to some property of cyclone motion and not to the direction of the wind. In secondary cyclones, as viewed on a synoptic chart, the area of rain and cloud sometimes appears to cover the area of shallow gradients inside the secondary; at other times the rain especially seems confined to the partial ring of steeper gradients which surround the secondary on the side of the nearest area of high pressure. The most striking difference between a secondary and primary cyclone is the great amount of rain and cloud with absence of wind developed in the former compared with the less rain and cloud but the greater wind developed in the latter. To a single observer the characteristic features of a secondary are a uniformly overcast sky, with a peculiar stagnant motion of the clouds, and a very gloomy appearance and oppressive state of the atmosphere. When the rain comes on it is usually very heavy and falls straight, and in its general appearance and surroundings is very different from the driving drizzling rain, so characteristic of the front of a primary cyclone. Another very marked difference between the rain in a primary and secondary cyclone is the motion of the barometer. In a primary the misty rain in front is accompanied by a rapidly falling barometer, while the hard rain in rear is accompanied by a

rising barometer; but in a secondary the barometer is usually perfectly stationary with a slight but quick motion at the beginning and end of the rain, either up or down, according to the general direction of barometric change. This heavy rain and cloud, with a steady barometer, was long very puzzling, and it is only since the publication of the carefully-drawn charts of the Meteorological Office that its true nature has been (*Page* 8) discoverable. In anti-cylones viewed on a synoptic chart, the position of blue sky, cloud or fog seems very capricious, but to a single observer a certain general character is readily perceptible; but as it is much less marked than that in cyclones, it is more easily masked by diurnal, local, and seasonal variations. In a general way the weather is fine or at least quiet; and though, in the calm centre especially, thick fogs are often found, and cloud in other parts, the surroundings are so different, that they can rarely be mistaken for cyclone weather. There is always a certain coolness in the air, though if the sun shines it is very hot; in fact the terms "radiation weather" and "radiation temperature" would generally best describe anti-cyclonic weather. There is no doubt that in this country rain sometimes falls in an anti-cyclone, and in France it seems to be tolerably common. To a single observer the rain is usually in short showers, with rather a high sky, and the general appearance is different from that in either primary or secondary cyclones; the showers are very often accompanied by a slight irregular motion of the barometer, and as they are very short and of small extent are probably due to some local disturbance. [Illustrations are given of the general principles from the weather prevailing on specified days in various parts of the British (*Page* 12) Isles and contiguous area. The addition referred to below was made in March.] The following are additional illustrations of the term intensity as applied to weather. (*Page* 13) Take a cyclone of a certain size and shape, and conceive another of the same size and shape moving in the same direction at the same rate, but in which the isobars, instead of representing a difference of ·2in., represent a difference of only ·1in., then we should have two cyclones differing in nothing except intensity, which would be greater in the first than in the second. The corresponding difference of weather would be shown in a less continuous area of rain near the centre, in a smaller extension of cloud round the rain, and in a less total rainfall all over the country during the cyclone's motion. Where squalls occurred in the first cyclone they would be replaced in the second by brisk showers, and the weather generally would be more deficient in those properties to which the words hardness or severity are usually applied, but the general character and position of the front and rear would remain unaltered. Thus we see that this kind of intensity depends on the steepness of the gradients in a single cyclone. The other kind of intensity refers rather to that sequence or tract of weather to which the term broken would be applied. From synoptic charts broken weather is found to be either the product of small quick-moving cyclones, which only exist a very short time, or of frequent secondaries; in contradistinction to the weather produced by large shallow-gradient cyclones, moving slowly and lasting some days, which would be associated with more settled weather. The difference between these two kinds of intensity is analogous to single heavy gusts of wind being as much a sign of great atmospheric disturbance as numerous short puffs, although they proceed from different causes. With regard to the line dividing the front and rear of a cyclone, it can always be approximately determined by drawing a series of sections of pressure across the cyclone, parallel to its path. The line along which each of the sections changes from rise to fall is the line required, and is obviously independent of the deepening or filling up of the cyclone. Sometimes when a cyclone is filling up very rapidly the barometer rises even when the central line is approaching the observer; and conversely, when a cyclone is deepening rapidly the barometer continues to fall after the central line has passed, but the relation of wind and weather, relative to the cyclone centre, always remains the same. In this fact we have the explanation of many seeming anomalies between the apparent motion of the barometer and the actual state of the weather.

GENERAL NOTES.

1878 (*continued.*)

Abercromby, Hon. Ralph. *On the Application of Harmonic Analysis to the Reduction of Meteorological Observations, and on the General Method of Meteorology. Q. Journ. Meteorol. Soc.*, iv. p. 141–156. Read April 18. Published in No. for July. (*ra.*)

(*Page* 141.) The paper illustrates harmonic analysis by taking pressure as an example, and tracing the physical and geometrical meaning of every step from the barographic record till the tabulated records are exhibited in a harmonic series. But comparing this curve with the traces from which it is derived we see that the result of averaging is to eliminate all the information which might have been derived from them relative to the position or passage of cyclones, squalls, etc., as they occur at irregular hours, in fact all that makes up changes of weather, and that only the regular periodic variation is left. Also that this diurnal mean curve is only the graphical representation of the fact that there is a diurnal variation of the barometer, which is usually of a certain magnitude, and occurs usually at certain hours; but the curve gives no clue to the cause of this variation beyond the obvious inference that as its period is one day, the sun is probably the primary agent. During an arctic winter the resultant curve of daily mean pressure will be an irregular line whose fluctuations have no physical meaning, but represent the fact that the cyclonic variations have not balanced in so short a time. If now we take the same series of figures representing the mean pressure at every hour of the day and combine them by Bessel's formula, we get a harmonic series of the form $P = A + B (\sin \Theta + C) + D \sin (2 \Theta + E) +$ etc., and if we plot the curve represented by the above equation with the proper co-efficients we find that it is almost identical with the former curve of mean pressure. In fact this formula gives, in a single expression, the whole of the isolated tabulated values in a very convenient manner; and as the co-efficients can be calculated for any number of different places it is easy to compare the respective characters of their diurnal variation; so when mean values are used the harmonic analysis is the most convenient and perfect method of averaging. But it is most important to observe that a harmonic series can be made to fit any arbitrary function whose law is unknown, but of which numerical values can be determined; that in this case the formula only gives the numerical, but not the physical, law of the variation of the barometer by expressing in mathematical language the fact that at a certain hour the pressure is a certain distance from the mean, without any reference to the physical cause, so that it is merely the algebraic embodiment of a fact. It is also evident that nothing more is learnt from the harmonic series than from inspection of the curve formed by plotting the mean values directly. But there is another totally different view of a harmonic series which has been very strongly advocated by Sir William Thomson, viz., that when the numerical values of a physical phenomenon are reduced to a harmonic series, each algebraical term corresponds with one of the physical constituents of the total variation represented by the whole series. Each term of such series represents that class of motion called harmonic, which in a simple form he has shown to play a prominent part in physical science; while the more complex harmonic series he has used with great success in tidal investigations. (*Page* 143.) The general idea seems to be that as a matter of observation harmonic

action is almost a great physical principle; and that just as in complex waves the primary wave is naturally subdivided into 1, 2, 3, etc., parts, so in complex harmonic motion the primary is naturally subdivided into motions corresponding to Θ, 2 Θ, 3 Θ, ... etc.; so that in thus analysing an unknown function into harmonic constituents we have a great engine of discovery, and not merely a formula that puts into a short compact form a number of isolated facts, or that approximates to an arbitrary function. The author does not feel competent to enter into the general principles involved either in harmonic motions, or the curious analogies which can often be traced between analytic symbols and physical phenomena; but from a meteorological point of view, and considering only the diurnal variation of the barometer, he would remark, that neither method gives much clue to the physical causes, beyond the probability that it has something to do with day and night. In whichever way we look at harmonic analysis, its value must depend on our estimate of the use of averages, or of the (*Page* 144) statistical method generally in meteorology. A large and most useful class of statistical results have been derived by taking the statistical value of different elements, and considering their amount locally or by comparison with surrounding places.

The introduction of statistical methods was a great step in meteorology, but it is now necessary to examine where these methods fail, and why they can never raise meteorology to the rank of an exact science. The failure of statistical methods may principally be referred to three causes: (1) that, when applied to the fluctuations of any one element, they only take hold of periodic phenomena; (2) that of these periodic phenomena averages only give the facts of their variation, and often furnish no clue to their causes or laws: (3) that when applied to the amount of any one element or to the discussion of synoptic maps, phenomena are often classed together which are not really identical, but have only one common property. We will now consider these sources of failure separately. I. The elimination in these results of the effects of cyclones and anticyclones leads naturally to the consideration of what part synoptic charts must play in the future study of meteorology. Though such charts have been constructed for more than twelve years, meteorologists are by no means agreed as to their use or meaning, and the author therefore proposes to make a few remarks on their relation to the general problems of meteorology, and to point out the method of attacking certain questions by their means. In the first place the study of synoptic charts gives an answer to the question "what is weather?" Weather is the product of the passage of cyclones or anticyclones over any place. In temperate regions the circulation of the atmosphere, the general scheme of which is at present entirely unknown, always takes broadly the form of cyclones or anticyclones, whose position and shape are in a state of perpetual change, subject to numerous local, diurnal, seasonal and other variations, the weather at any part of either always possesses the same characters; so that the weather over any area at any instant is the result of their position, and the sequence of weather over any spot is the result of their motion. Hence the problems for the meteorologist to solve, as regards weather, are: (1) To determine the character of cyclone and anticyclone weather, which would give the explanation of the observed weather at any moment over any area—a very complete solution of which is certainly possible. (2) To explain the observed sequence and variation of (*Page* 145) each element over any spot by defining the position and motion of the cyclones or anticyclones that have passed over it. (3) To study the motions of cyclones and anticyclones so as to discover the nature and laws of their changes, so that given their position at any moment, their future course and resulting weather may be forecast. Very little progress has been made in this direction. If this general view of weather be correct, meteorology is essentially an observational science, for the physical conditions are not such as can be reproduced in the laboratory, nor are the results capable of being expressed in mathematical language, or in simple maxims. The views

just enunciated point to a great change in the way of looking at weather prognostics. If every part of a cyclone or anticyclone has a characteristic appearance, then every prognostic must be studied with reference to the synoptic conditions during which it is observed, and all that any such prognostic can do is to enable an observer to identify his position relatively to the cyclone or anticyclone. An observer with telegraphic nformation could often forecast the result by considering the surrounding pressure. The following is an illustration of an important class of questions whose solution can already be roughly sketched since the introduction of synoptic charts. From them it is easily seen that the positions of persistent anticyclones, and of areas of depression that are constantly traversed by cyclones, are roughly defined by the distribution of land and sea; and some day, when it is more worked out, it will be possible to say what alteration in climate would be produced by a change in the position of land and (*Page* 146) sea. For instance, in winter there is usually a persistent anticyclone over Siberia, which stretches across Central Europe, while the North Atlantic is covered by a persistent area of depression, in which cyclones are constantly formed in such a position as to leave England traversed by warm S.W. winds. Observations on the general circulation of the atmosphere show conclusively that the Siberian anticyclone is due to the cold radiation from the land. Hence, if Siberia were submerged, the anticyclone would disappear, the Atlantic cyclones would be able to move east, and, with a larger proportion of west winds, the climate of England would grow colder. Again, there is another class of questions that it has been attempted to solve solely by statistics, but which the author ventures to think can only be satisfactorily handled by reference to synoptic charts, viz., the connection of rainfall with sunspots. Take, for example, the rainfall in the north of Scotland for 1872, a year of sunspot maximum. In that year, according to Buchan, the rainfall over a small area in the valley of the Dee was 75 per cent. above the average, while within 120 miles of this area, in a north-west direction round Cape Wrath, there was a large region where the rainfall was below the average. Taken as bald statistics, it would be difficult to say from this whether rainfall was increased or diminished by a sunspot maximum. But if we consider the synoptic history of the year we find that it was characterised both by a great diminution in the number of large cyclones moving in a N.E. direction at some distance from Great Britain, which expose our west and N.W. coasts to wet S.W. winds, and leave our east coasts comparatively dry; and by a great increase of small cyclones and secondaries, both of which are always very wet, crossing our islands in an east or even S.E. direction, thereby greatly increasing the rainfall on our east coasts, and in the case of cyclones going S.E. into the German Ocean, often leaving our N.W. coasts comparatively dry. It appears, therefore, in this case a year of sunspot maximum was associated with a very well marked and readily described variation in the usual synoptic conditions of the whole of western Europe; and if this is confirmed in future years it will then be safe to connect sunspots with the general circulation of the atmosphere, which can never be done so long as we consider only one meteorological element. In connection with this it may be observed that the year 1877, a sunspot minimum, was remarkable for the small number of secondaries which crossed Great Britain. Similarly with regard to the connection of Indian rainfall and sunspots, it seems doubtful whether pure statistics can ever lead to a satisfactory result. Indian rainfall is so local and so dependent on both monsoons that, unless the rainfall returns are carefully considered (*Page* 147) from a meteorological point of view, and daily synoptic charts constructed, to show if there is really a cyclical variation in the position or force of the monsoons, we shall never be justified in asserting that there is a real physical connection between sunspots and weather. There is a further great advantage in this method of treating the question of sunspots. The same synoptic investigation which is required to deal with rainfall also supplies the explanation of the decrease of temperature, increased proportion of west winds, and unusual number of thunderstorms over W. Europe in

1872. What has already been explained with reference to the harmonic curve of mean daily pressure is capable of extension to every algebraic expression, viz., that it only expresses in symbolical letters facts or ideas which might be expressed more cumbersomely in words. Hence it is impossible that there should be an algebraic criterion of fact as a logical touchstone of what is true; that is to say, that letter symbols discover no more than word symbols. Therefore it is evident that if we have two sets of phenomena to compare, which can both be shown graphically in a similar manner, no mathematical combination can either alter or improve the judgment which the eye will form as to their probable coincidence or otherwise. The consideration of the foregoing questions as to change or recurrence of weather brings forward very prominently a great want, which synoptic charts may be used to supply, viz., a description, in synoptic terms, of cold, hot, wet, dry and stormy seasons, etc., or of long tracts of weather, as referred to the position and motion of cyclones and anticyclones. One source of increased cold has been already mentioned as depending on the position of cyclone paths, but much cold in winter is due to the presence of anticyclones with their radiation; and there are probably other conditions of wet years than those of 1872; and till these and similar groups are properly defined and classified, we shall never be able properly to discuss questions of climate, or to say that the recurrence of any one element is more than a mere coincidence. Before leaving this subject the author wishes to make a few remarks on the attempted application of statistics to the discussion of synoptic charts, which up to the present has not led to much result, nor does he think it ever will. We have seen that if there are no constant periodical phenomena a mean value is only the arithmetical result of certain unbalanced observations. For instance the exact direction of the wind at any part of a (*Page* 148) cyclone is variable, depending principally on the position of the steepest gradient, so that the mean direction of the wind at that point merely signifies that it is usually in that direction, but does not say what it would be in any given type of cyclone. Again the mean velocity of a cyclone has no physical meaning, but only states an arithmetical result, and is of no use in forecasting the path of any particular cyclone. To carry out the investigations referred to in this part of the paper it is evidently absolutely necessary to construct synoptic charts for certainly the whole northern hemisphere and probably also for the southern hemisphere, for by no other means will it be possible to discover that general scheme of the circulation of the atmosphere on which the whole science of meteorology appears to rest.

II. Before dealing with the second reason of the failure of averages, viz., that when applied to periodic variations they only give the facts and not the causes, the author wishes to point out the position of diurnal periodic phenomena generally in meteorology. If we look at any set of synoptic charts we see that the cyclones and anticyclones seem to go on their course tolerably independent of day or night; while if we look at any set of meteorograms we see that every element has a diurnal variation. In some, as in barometric pressure and direction of the wind, the diurnal variation is small compared to the cyclonic; while in others, as in temperature and velocity of wind, the diurnal variation is large as compared with the cyclonic. An inspection of any set of barograms shows that the diurnal variation of pressure is simply a small fluctuation overlying either cyclone or anticyclone, and an inspection of synoptic charts for any hour shows that the direction and force of the wind are always determined by the position of cyclones and steepness of gradients; while in a former paper the author has shown that the general character of the appearance of weather is determined by the position of cyclones, though modified by a diurnal variation; whence the conclusion seems to be that the primary character of weather in its broadest sense (*Page* 149) is determined by the position of cyclones and anticyclones, while every element has a diurnal variation superimposed on the cyclone character. We have seen, in discussing pressure variation, that the result of taking the mean value for every hour

of the day is to eliminate the effect of cyclones and leave only the fact and average amount of the diurnal variation. Also that, whether we consider the variation as an observed fact or as a harmonic component, we have no clue to its cause other than considerations as to the hours of its occurrence may suggest. In the following remarks the author does not profess to solve the question of diurnal barometric variations, but merely to show the means by which only, he believes, the solution ever can be worked out. The method proposed is simply, instead of taking mean values, to take every day on its own merits, and to observe what kind of weather is associated with large diurnal and what with small diurnal variations, and how different kinds of weather affect the times of maxima and minima. For instance, once during the summer of 1877 in London there were several fine days at the edge of an anticyclone, during which, though one would usually have expected a considerable 4 A.M. minimum the barographic trace showed very slight indications, if any; the author observed that on those mornings, there was an unusual amount of wind about 4 A.M., and if this is confirmed by future observation, it would point to the conclusion that wind is not favourable to the formation of the 4 A.M. minimum. Then as to the 10 A.M. maximum, if we look at the barographic trace for May 27, 1877, we see that superimposed on the general rise of the barometer between 4 A.M. and 11 A.M. there is a very slight depression. The author's observations for the day are not very complete, but a similar depression is very common, and in many cases he has observed it to be associated with the temporary formation of heavy clouds about that time of the day. If this also is confirmed by future observation it would point to the conclusion that either overcasting of the sky or the formation of cloud interfere with those statical or dynamical conditions which produce the 10 A.M. maximum. Then as to the 4 P.M. minimum, Buchan has conclusively shown that at Valencia and over the North Atlantic generally it is smaller in summer than in winter; while at Kew and in Continental Europe generally the reverse is the case; and even within so short a distance as 50 miles the author has observed that the kind of weather which would give a large 4 P.M. minimum in London only gives a small one at Brighton, clearly pointing to the influence of land or water in the production of this variation. The author has also pointed out, in a former paper, that there are critical periods of the formation or disappearance of cloud or fog superimposed on the general cyclone or anticyclone character of weather corresponding with the hours of diurnal barometric maxima and minima, and by combining the above and many other observations of a similar nature it will certainly be possible some day to explain (*Page* 150) these diurnal variations. The chief interest of diurnal barometer variation lies in the difficulty of explaining it, for an inspection of the barograms illustrating this paper, and the general argument, will show that it is simply a very secondary phenomenon superimposed on cyclones, and that even if we were now in possession of its complete explanation we should be no nearer a knowledge of the laws of cyclone motion on which all weather forecasting depends. A similar line of observation will be necessary to discover the cause of the numerous other diurnal variations which are still unexplained by meteorologists, and of which any combination of mean values can only give the facts. Passing from unknown to known causes, the method proposed may be compared to taking the mean temperature of every hour of the day, which we shall find is represented by a single headed curve with a minimum about 4 and a maximum about 2 A.M. and 2 P.M. Then if the recognition of the fact did not suggest the cause, by taking many single thermograms and observing that a small diurnal range is produced by cloud which at night reduces the cold and by day reduces the sun's rays—also that a temporary clearing of the sky might make the minimum at almost any hour of the day—and that these changes are always secondary to those produced by cyclonic alterations in the direction of the wind—we should conclude, even if it were not otherwise obvious, that terrestrial radiation by night and solar radiation by day, were the causes of the diurnal range of temperature.

III. We now come to the third source of failure in the use of averages to make meteorology a science, viz., that when applied to values or occurrence of any element, phenomena are treated as identical which have really only one common property. Take for instance the occurrence of rain. The commonest occurrence of rain in this country is in cyclone, accompanied, to a single observer, by a sharp fall of the barometer; but heavy rain also often falls in thunderstorms with a characteristic sharp rise of the barometer, and also more rarely with a flat barometer associated with secondaries, as shown on July 1, 1877 [for London], where rain began about the end of the small step-like fall of the barometer a little before 6 A.M., and continued during the time of steady barometer till the second step-like fall about 4 P.M. We see then that there are certainly three distinct states of atmospheric motion which are associated with rain; and therefore, deductions drawn from the mean value of rainfall which masses all these sources of rain together, must necessarily fail to be of any scientific value. Again, there are several sources of cold weather in this country; for it may either come with an (*Page* 151) east wind and a high pressure over Norway; or with N.W. wind with high pressure to the N.W. of Scotland; or else with the calms and radiation of an anticyclone, stretching northwards from France. So if we take the general circulation of the atmosphere, as shown by synoptic maps, to be the ultimate cause of weather, we have at least three different conditions of such circulation, but with one property in common, namely, cold. And if we attempt to generalise on the recurrence of cold merely from records of a low thermometer, without reference to the synoptic conditions of its occurrence, we are treating as identical phenomena which have really only the one common property of cold, and the results can only lead to error and confusion. A similar line of argument might be applied to every meteorological element. The importance of thus discriminating between different kinds of any phenomenon is most seen in discussing questions of cyclical variation and recurrence, as may be seen by reference to what has been said relative to the connection between rainfall and sunspots. The above method of dealing with questions of rainfall also helps to show very clearly where statistics are useful, and yet fail to make a science. If a distinctive name were (*Page* 152) wanted for this method it might be called the "specific" method, since it endeavours to discover causes by dealing with specific instances rather than by massing (*Page* 154) many results together. Note added June 17. The following are additional illustrations of the idea of harmonic analysis. In the first place it should be noted that in a harmonic series no combination of terms containing Θ can give rise to terms involving $2\ \Theta$, $3\ \Theta$, etc., so that if the diurnal variation of the barometer is due to the interference of the temperature and pressure of dry and moist air, it could not be expressed in a harmonic series. Also that the whole principle of the propagation of harmonic components involves the independence of the causes represented by Θ, $2\ \Theta$, etc. As this view of the subject is little known, the author may perhaps give the following extract of a letter from Sir William Thomson to himself, dated May 28, 1878, relative to a part of the preceding portion of this paper. "Take for example the barometric variation. This depends entirely on the sun's heat, while the semi-diurnal harmonic constituent largely exceeds the diurnal. Now, in the thermometric variation, the diurnal harmonic constituent greatly exceeds the semi-diurnal. If we could set aside the disturbing influence of cyclones we should probably find that the diurnal harmonic constituent of the barometric variation would be the same as if there were no semi-diurnal variation of either the barometer or thermometer, and the diurnal variation were what it is. So of the semi-diurnal, we should probably see it to depend simply upon the semi-diurnal harmonic constituent of the thermometer. This is undoubtedly a key towards a physical explanation of the barometric variation. It is probable that there is a fundamental mode of simple harmonic vibration of the atmosphere suitable for excitation of the semi-diurnal harmonic variation of temperature, whose period agrees much more nearly with twelve hours than with twenty-four hours, the period of a harmonic

vibration suitable for excitation by the diurnal simple harmonic constituent of the thermometer. The subject is at present quite open for mathematical theory; but the mathematical investigation, if not helped, will at all events be rendered more fruitful by extensive data from observation analysed into the two terms of diurnal and semi-diurnal periods, with proper treatment for the variations of the amplitudes and epochs of these terms for the season of the year." The whole question, then, of the application of harmonic analysis to meteorology turns round how much meteorologists are prepared to accept certain dynamical principles connected with vibrations as an explanation of the observed phenomena; and whether, up to the present time, any trace of such vibrations has been discovered. Allusion was made in the discussion on this paper to a method of averaging adopted by the late J. C. Bloxam in reducing his sixteen years' observations at Newport. A short account of it in his own words may be acceptable. After pointing out the difficulty to be contended with in determining the mean annual daily (*Page* 155) temperature by simply ascertaining the mean values belonging to a long series of years for each day, is the liability in the reducing process to obliterate the normal as well as the abnormal irregularities which belong to the secular variation in cycles, he goes on to say that his values were reduced by the following method. There being sixteen consecutive years to deal with, it is better to combine the whole of these together in mean values; but if there had been twenty or thirty, or any larger number of years, to deal with, it might have been better to dispose of these in successive groups of twelve years each, in the same method as that used for the successive days. The method used is founded on the principle that the mean value of nine or eleven consecutive days gives more accurately the normal value for the central date of the nine or eleven, as the case may be, than the identical value which may happen to fall on that date; and so, the value assigned to each day in the year is the mean value of a given number of days on each side of its own date. The number of days adopted for the mean is ten, this being by far the most convenient number for calculation; and the whole series of 365 days are thus made up of decadal means; the first mean value representing the decade 1-10; the second 2-11; the third 3-12; and so on. The date for the first mean value is 5½; the second 6½; and so on. This process having been carried on all through the year, the new series of mean decadal daily values thus obtained is in turn treated in the same way; and now the dates become whole numbers again. This process is reiterated until the resulting values constitute regularly increasing and decreasing quantities, and no longer, except that in consequence of using the number 10, it becomes necessary always to have an even number of reductions in order to obtain whole numbers for the dates. By proceeding in this way the normal irregularities are preserved, whilst the small irregularities which can only be accidental are sufficiently obliterated from the thermometric values by repeating the process four times over. The same is the case with the dew point values, but with the other particulars a twofold reduction is found to suffice; but, in order to reduce the thermometric values to one line of constant ascent and another of constant descent, it was found necessary to repeat the process twenty-two times. It may elicit some useful facts to carry the process to this extent, but for general purposes, and more especially for the purpose of determining the daily normal values, it becomes a process of derangement rather than of correct arrangement. Now if we look at any ten days' successive thermograms, it is easy to see what the meaning is of taking the mean temperature for each day, and then the mean of the ten days, namely, that a mean temperature of say 50° tells very little about the kind of weather, for it may either be the result of a maximum and minimum of 65° and 35° in fine weather; or of 55° and 45° in dull, overcast weather, and that massing all ten days together completely destroys their individuality; but it is very difficult to say what the meaning of a mean decade of the second order would be; in fact it is very doubtful whether it has any, (*Page* 156) except an arithmetical significance. The result of the procees is, however,

easily traced. As a matter of fact in this country [England] the annual march of temperature is not a uniformly ascending and descending line, but has interruptions of cold periods, notably about February 10 and May 14, owing to the occurrence about these dates of cold anticyclones; and we see that Mr. Bloxam's test of the utility of his process is the disappearance of these important facts. The author finds, for instance, from Mr. Bloxam's own tables, that the mean temperature for Feb. 11, derived from the mean average of the sixteen years, is 36·94°, while the value obtained by a fourfold decadal reduction is 38·66°, and that obtained by a 22-fold reduction is 39·43°. The result therefore of the process is to destroy what meaning the original curve possessed, and the author believes that a similar result must necessarily attend any other application of the method. If the curve of mean daily temperature is plotted, the periodical irregularities are detected at a glance, and in every case of cyclical recurrence the author believes the graphical to be superior to any arithmetical process.

Abercromby, Hon. Ralph. *Q. Journ. Meteorol. Soc.*, iv. p. 198 et seq. Published in No. for Oct. (*ra.*)

(*Page* 198.) The method hitherto universally adopted in treating of the diurnal variations of the barometer has been to take the mean value of a large number of observations at each hour of the day, and to draw deductions from the average amount of variation thus determined. The diurnal variation is superimposed on larger fluctuations, and in order to ascertain the causes of the variations it is desirable to be able to measure the actual amount of variation on any particular day. This cannot be done when the non-diurnal fluctuations are curved; but when the general motion shown by the barographic trace seems to be a straight line, the amount of diurnal variation which (*Page* 199) overrides it can be approximately determined in the following way. Find the mean pressure for the day; mark this height on the noon ordinate, then draw a straight line through this point in such a way that it intersects the two midnight (*Page* 200) ordinates at the same distance below the trace. The value of the method depends on the diurnal variation being the same at the first as at the second midnight, which is not always the case. The difference is, however, always small. (Note, added in July.) Kämtz suggested a similar method in Q. Journ. Meteorol. Soc., III. p. 130, in the following words: If therefore, at one place, hourly observations have been made for several years, and if for each month, the mean of the temperature observed at the same hour be taken, it is not strictly correct, if we consider these means obtained to be such as belong exactly to this day; but we have in the numbers found, on the one hand, quantities belonging to the daily period, and, on the other hand, the variations which correspond to the march of temperature from the end of the previous to the beginning of the following day. If we draw the yearly temperature curve from many years' observations, the portion which corresponds to April is nearly a straight line, therefore the temperature rises from one day to the following day about the same quantity. If then, according to these observations, the 1st of May was 6° warmer than the 31st of March, the mean of each day would be about 0·2° warmer than the previous day; if we distribute this over the hours each would take $\frac{0{\cdot}2°}{24} = 0{\cdot}0083°$; if the hours are reckoned from 1 to 24, indifferently as to which hour 1 corresponds, the 24th is, owing to this circumstance, 0·19° warmer than that indicated by 1, and in a strict calculation of the period regard must be paid to this change in each individual calculation. (*Page* 201.) Kämtz's method is correct where averages are used, which give the level of variation; and in general idea is the same as the method employed in this paper. Still the author believes there is a certain amount of novelty in the paper, as it is the first attempt that has been made to determine diurnal variation from observations of a single day, and to dispense altogether with the use of averages; and secondly, that

there is some novelty in the method of finding the level of variation. [The method is applied by the one author to the barometric condition of the air, and by the other to temperature; but its application is more general than this. Moreover, the method itself might have a more general scope, the principle being the superposition of curves of periodicities of all lengths upon straight lines representing the general direction of longer fluctuations. In Kämtz's case, the diurnal curve is superimposed on the annual line for a month; in Abercromby's, the diurnal curve is superimposed on the larger variation and mean lines for the day.]

Archibald, E. D. (*B.* 1.)

April 23. (*Page* 3.) The sun's heat is notoriously the source of all climates, and changes in the amount of heat radiated from its surface are now regarded as causing for the most part the changes in terrestrial weather. The solar spots, according to Schwabe, Wolf, De La Rue, Stewart and Loewy, undergo a complete cycle of variation every 11·11 years, or according to De La Rue more accurately 11·07 years; the period of increase from minimum to maximum comprising 3·52 years, and of decrease from maximum to minimum 7·55 years. Lamont gives 10·43 years as the length of the period. As there is a close connection between the solar changes and the periods of terrestrial magnetism, it has been conjectured that if such magnetic changes are due to corresponding changes in terrestrial meteorological currents, some connection might be found to exist between the secular variations in sun-spot frequency, and those in the different elements of terrestrial meteorology. There is then some ground for believing that a connection exists between the eleven-year period of solar maculation and some kind of emission dependent upon the particular meteorological or thermal conditions of the sun's surface with its accompanying train of terrestrial meteorological and magnetical effects. It is here assumed that the magnetical disturbances follow and are dependent on the meteorological, an assumption supported by Balfour Stewart in his address to the British Association in 1875. From the earliest times we find a popular tendency to expect the weather to recur in cycles of about 10 or 12 years. Sayce, in 'Nature,' No. 310, says the Babylonians used cycles of 12 years, during which they expected the same weather to recur, and as their years only contained 300 days, this would correspond to 11·8 of our years. [The remainder of the paper deals mainly with solar physics and the probable close connection between these, terrestrial magnetism, and terrestrial meteorology.]

Broun, J. A. (*B.* 2.)

(*Page* 126.) I propose considering some of the questions raised by Faye. He decides that the moon does not influence weather; but then his conclusion is based (*Page* 127) solely on the weather register kept at one place, Vigevano. Faye decides that the moon does not reflect heat sufficient to make a change of $\frac{1}{1000}$th of a degree Fahr. If then the moon's action does dissipate clouds, it must act otherwise than by heat.

Buchan, A. (*B.* 3.)

(*Page* 506.) To test the value of Meldrum's method of inquiry as to the relation of rainfall cycles with sun spots, I have treated Wolf's relative numbers of sunspots as follows:—

1	1·6	8·1	26·3	13·1	7·7	31·4	14·7		..
2	4·9	16·2	9·4	*19·8	5·1	14·7	11·6	1	14·9
3	12·6	35·0	13·3	38·3	22·9	8·8	21·8	2	25·4
4	16·2	51·2	59·0	59·6	56·2	36·8	46·5	3	48·8
5	35·2	62·1	119·3	97·4	90·3	78·6	80·5	4	77·0
6	46·9	67·1	136·9	124·9	94·8	131·8	100·4	5	91·1
7	39·9	67·0	104·1	95·4	77·7	113·8	83·0	6	83·0
8	29·7	50·4	83·4	69·8	61·0	99·7	65·7	7	65·6
9	23·5	26·3	61·8	63·2	45·4	67·7	48·0	8	49·0
10	16·2	9·4	38·5	52·7	45·2	43·1	34·2	9	34·6
11	6·1	13·3	23·0	38·5	31·4	18·9	21·9	10	24·6
12	3·9	59·0	13·1	21·0	14·7	11·3	20·5	11	22·5
13	2·6	119·3	19·3	7·7	8·8	7·0	27·5		..
	1	2	3	4	5	6	7		8

1 = 1811–1823.
2 = 1824–1836.
3 = 1832–1844.
4 = 1843–1855.
5 = 1855–1867.
6 = 1865–1877.
7 Means.
8 Mean Cycle.

* 19·8, in 5th col., 2nd line, is evidently a misprint for 19·3.

Collins, J. J. (*B.* 8.)

(*Page* 4.) The weather predictions cabled by the 'New York Herald' to its London office, commenced February 14, 1877, and a large percentage were fulfilled. Except in (*Page* 5) few cases recent works on meteorology are barren of original information. They are chiefly made up of quotations from earlier works and the experience of isolated observers. We find in America that many branches of trade are seriously affected by weather changes, and that timely warnings are calculated to insure against losses that would in their absence be sustained. The great-grain producing districts of the Western States send their produce to the eastern sea-board. Sudden and severe storms affect the conditions of the roads, and thus cause delays, at the same time that the produce is liable to damage. Hence both producer and dealer welcome all information as to weather. The same state of feeling must exist wherever trade flourishes and agriculture represents wealth. To the seaman a timely warning is of paramount importance. Timely storm-signals are useful to an army on campaign, and the variations in the conditions of the weather must be recognized in all the operations of an army, otherwise great disasters may overtake it. Many difficulties incidental to warfare would be avoided by having a special military service of meteorologists.

Meldrum, C. (*B.* 20.)

(*Page* 448.) From an examination of the rainfall (1872 to 1875) at 144 stations in different parts of the world, the conclusion is drawn that there is a rainfall-cycle of the same duration as the sunspot-cycle, and nearly coincident with it, both the sun-spots and the rainfall attaining a minimum in the eleventh, first, and second years of the cycle, and a maximum in the fifth. As Hunter found this to be so, I examined his method. A remarkable rainfall-cycle had been previously obtained for Bombay nearly coincident with the sun-spot cycle, as also for Anjarakandy, Calcutta, and Nagpur. Hunter's method was to commence with 1876, and taking backward as far as the

register extended for periods of eleven years each, and then finding the mean rainfall for each series of years in the common period. My method being different, the results are not comparable. The sun-spot period being one of about eleven years, and the maximum epoch occurring on an average 3·7 years after the previous maximum, and the next minimum 7·4 years after the maximum, I found the best way was to start either from a maximum or a minimum year, and then to take the proper number of years before and after the epochal year. Commencing with a maximum year for instance, I (*Page* 449) took five years before it and seven years after it. Then, with a view of reducing the effects of the so-called non-periodic variations, I took a mean of the rainfall in the first and third of the thirteen series, and a mean of that mean and of the rainfall in the second series, and so on. This gave me eleven new means, which I called the "mean cycle." Again, starting with a minimum year, I took eight years before and four after it, and found eleven other new means in the same way. To each set of results, or to a combination of them, I then applied interpolation formulæ, and found a well-marked coincidence between the sun-spot and rainfall variations. This is illustrated by means of the Madras rainfall, which shows a double oscillation during a sun-(*Page* 450) spot period. Dr. Hunter considers that the evidence as regards European and American rainfall is against a periodicity, but it seems to me it indicates a periodicity which closely corresponds with that of sun-spots. Thus the mean for about 128 stations in Europe and America are these:—

Years of cycles ..	1	2	3	4	5	6	7	8	9	10	11
Sunspots	−31·7	19·5	3·5	+28·8	39·5	29·5	10·4	−4·9	14·8	21·2	19·4
Rainfall Variation	−1·9	1·43	·09	+·71	·82	1·26	1·46	·78	−·1	·65	·55

Having worked at the subject for six years, I have concluded that the whole evidence is satisfactory as to the existence of a connection between sun-spots and terrestrial magnetism.

Meldrum, C. (*Nature*, xviii.)

(*Page* 561.) [He gives tables of sun-spots from Wolf's relative numbers, having the maximum years in the sixth line, and the minimum years in the eighth line. The first is the same as that given by Buchan, with the following differences:—

3rd column 6th line	67·2
„ 8th „	59·4
5th „ 2nd „	19·3
Mean cycle column 5th line	91·9

He adds a variation column as follows:—]

1	− 33·9
2	− 23·4
3	0·0
4	+ 28·2
5	+ 43·1
6	+ 34·2
7	+ 16·8
8	+ 0·2
9	− 14·2
10	− 24·2
11	− 26·3

The second table gives the sun-spot numbers from 1816 to 1872, arranged so that the minimum years are in the eighth line.

No.	1816 to 1828.	1826 to 1838.	1836 to 1848.	1849 to 1861.	1860 to 1872.	Means.	Mean Cycle.	Variation.
1	46·9	35·0	119·3	95·4	94·8	78·3		
2	39·9	51·2	136·9	69·8	77·7	75·1	73·1	+ 23·3
3	29·7	62·1	104·1	63·2	61·0	64·0	64·3	+ 14·5
4	23·5	67·2	83·4	52·7	45·4	54·4	54·6	+ 4·8
5	16·2	67 0	61·8	38·5	45·2	45·7	44·2	— 5·6
6	6·1	59·4	38·5	21·0	31·4	31·3	30·8	— 19·0
7	3·9	26·3	23·0	7·7	14·7	15·3	17·3	— 32·5
8	2·6	9·4	13·1	5·1	8·8	7·8	12·7	— 37·1
9	8·1	13·3	19·3	22·9	36·8	20·1	24·4	— 25·4
10	16·2	59·0	38·3	56·2	78·6	49·7	51·6	+ 1·8
11	35·0	119·3	59·6	90·3	131·8	87·2	80·7	+ 30·9
12	51·2	136·9	97·4	94·8	113·8	98·8	94·6	+ 44·8
13	62·1	104·1	124·9	77·7	99·7	95·7		

Meyer, A. G. (*B.* 31.)

(*Page* 621–625.) [Gives description of the weather-case, directions for reading it, and its uses.]

Neumayer, G. (*B.* 32.)

(*Page* 313.) The people generally take little interest in meteorology. The greatest progress has been made by the United States; next come England, Holland, France, and Denmark. The German Seewarte does its share in the international work.

Preston, Rev. T. A. *Q. Journ. Meteorol. Soc.* No. for Jan. (*ra.*)

(*Page* 55.) From the first table [which gives the dates of flowering of many plants at numerous localities in England] may be gathered the difference of climate between two stations. [The immediate context shows that climate here means temperature, and to a certain extent moisture.]

Nature. (Vol. xvii.)

(*Page* 211.) Faye, in the 'Annuaire du Bureau des Longitudes,' denies that any connection exists between either sun-spots, magnetic disturbances, or the motions of the moon, and variations of the weather.

Nature. (Vol. xviii.)

(*Page* 63.) Much diversity of opinion exists regarding the climatic effect of the sun (*Page* 83) upon the earth at the present time.—(Meteor. Soc., April 17.) Hon. R. Abercromby. The meaning of the harmonic analysis is shown in reference to average barometric pressure by tracing the geometrical and physical significance of every step from the barogram till the tabulated results are combined in a harmonic series. Whether we regard this series as an algebraic embodiment of a fact, or as a series of harmonic components, it is simply a method of averages, and our estimates of its value must depend upon the use of averages at all in meteorology. The failure of averages to make meteorology an exact science is traced to three causes:—1. That the process of (*Page* 84) averaging eliminates the variable effects of cyclones and anti-cyclones, on which all weather from day to day depends, and on this are based some general remarks on the use of synoptic charts, not only in explaining and forecasting weather, but also in attacking such problems as the influence of changes of the distribution of land and water on climates, and the cyclic recurrence of rain or cold. 2. That deductions from averages only give the facts, not the causes, of any periodic phenomena. The position of diurnal and other periodic variations in the general scheme of meteorology is then

pointed out, and it is shown that their causes can only be discovered by careful study of meteorograms from day to day. 3. That in taking averages, phenomena are often classed as identical which have not [=but] one common property. For instance, rain in this country is associated with at least three different conditions of atmospheric disturbance, and it is necessary to discriminate between these kinds before meteorology (*Page* 430) can be an exact science. During the eclipse of 1878 the corona was much (*Page* 431) less brilliant than usual. Associated with this are a small number of spots and a famine period. In 1871 there were many spots and a heavy rainfall, which were (*Page* 600) associated with a large corona. In all earthquake countries it is believed the weather is affected by such phenomena. Observations should be recorded showing (*Page* 619) the influence of earthquakes upon the weather. Mr. F. Chambers believes it probable that all abnormal meteorological variations are due to causes similar to, if not identical with, those which produce the normal variations. Indeed, says Chambers, (*Page* 620) the inference that most of the unusual variations of weather in tropical climates are induced by corresponding variations in the absolute heating power of the sun in the same manner that the seasonal variations are induced by those changes of heating power which depend on the relative motions of that body seems almost irresistible. If, then, the absolute variations of the sun's heat are fitful in their occurrence, and do not obey periodical laws, it will, perhaps, never be possible to predict by more than a few days in advance the unseasonal variations of weather induced by them; while if such laws can only be discovered, the possibility of our being able to predict their consequences is equally certain.

Nature. (*B.* 43.)

(*Page* 178.) Ley. The form and movements of the clouds are intimately connected with the relation of wind and weather to the distribution of barometric pressures. Changes in the clouds indicate to us alterations of wind and weather. From the use of weather maps a new science of the winds has originated, on which all attempts at weather forecast must be based.

1879.

Archibald, E. D. (*B.* 1.)

(*Page* 626.) Professor Piazzi Smyth evidently infers ('Nature,' xx. *page* 431) that changes in the condition of the sun must needs affect every part of the earth in the same way, whereas we have many meteorological analogies which favour the notion that totally opposite effects may arise in different parts of the earth from the action of the same primary cause. For example, it is generally assumed that the same tropical heat which gives the primary impulse to the desiccating N.-E. trade wind of subtropical latitudes furnishes the energy which exhibits itself in the almost constant precipitation under the equator. Any variation in the degree of this heat should consequently affect localities situated in the region of the trades and the equatorial calm belt in a diametrically opposite manner. Moreover, the notion that the British and Indian rainfalls vary together now is altogether inconsistent with the well-known want of similarity between them, both as regards seasonal distribution and annual quantity, in the past. Induction should be made from results which are derived from trustworthy data, and anticipated by a knowledge of admitted physical principles. As an example of the latter I would (*Page* 627) mention the secular period traced by S. A. Hill in the barometrical pressure of Calcutta. So far as we have gone in India we find years of few sun spots characterized by higher temperatures, greater wind velocity, and greater range of barometric pressure than those of many spots.

Baker, H. B. In *Annual Report of the Michigan State Board of Health for the year* 1878. 8vo. Lansing. 1879. (*ra.*)

(*Page* 213.) Meteorological conditions are known to have great influence on the health

of the people; and certain groups of such conditions are known to be coincident with, and are believed to cause, directly or indirectly, a very great many deaths during each year; such, for instance, as a large proportion of the deaths from diseases of the bowels in summer; and of deaths from croup, bronchitis, inflammation of the lungs, etc., in winter. Any study of the causes of disease with a view to their prevention must therefore include comparisons of their rates with statements of the meteorological conditions existing at the same time, or immediately preceding. Such comparisons can be made by years, by seasons, and by months, and will be facilitated by noting those years, seasons, or months, which are exceptional in any of the meteorological conditions observed, and ascertaining whether there were any exceptional facts concerning any disease which appear to correspond therewith; and if so, whether comparisons for series of years, seasons, or months, show such correspondence to be constant. Conversely exceptional times of disease supply peculiarly favourable opportunities for studying meteorological conditions which may influence the disease. In considering the question to what extent they are only incidental, all other conditions which can have influence in causing or modifying the disease must be kept in mind, or be separately considered. In order to eliminate the evidences of unknown or unconsidered influences, and of those which are only indirect or incidental, comparison must be made by different periods of time; as for instance, if a given disease is found to prevail most in years when certain (*Page* 214) meteorological conditions prevail, it is needful to learn whether it also prevails most in months when the same meteorological conditions prevail; because the disease might be caused by something coincident with such conditions, and which only occur once in a year, and can therefore be coincident only by years. Conversely it is useful to compare by years where a disease has been found coincident with certain meteorological conditions by months. Because of the interdependence of the several meteorological conditions it is usually the fact that when certain meteorological conditions are found to bear a more or less constant relation to a given disease, certain other meteorological conditions are found also to have nearly or quite as constant a relation, so that the cause of the disease is not certainly reached by means of this knowledge alone. Technical knowledge is requisite to appreciate the bearing of the evidence. There is much, however, that may be done in advancing this study by the meteorologist or physicist alone; because it not unfrequently happens that the usual harmony in the meteorological conditions is not maintained, some one or more being exceptionally prominent or absent as the case may be.

Burgess, A. H. (*B.* 7.)

(*Page* 313.) Suggests the establishment of a meteorological buoy in the track of storms at a distance from exposed coasts, and connected with them by telegraph wires, which will record the readings of the barometer and wind gauge. One might be (*Page* 314) placed 80 miles or so from Valenita. If found successful other readings could be taken, and other floating observatories established at certain distances apart This would give warnings of storms which would be almost sure to visit the coast.

Griffith, Rev. C. H. *Q. Journ. Meteorol. Soc.*, V. No. for Jan.

(*Page* 62.) I am convinced that all insects might with advantage be observed as weather indicators. The geometrical spiders are gifted with a remarkable perception of probable future conditions of the atmosphere, indeed M. Q. D' Tijonval has suggested that they are so accurate as weather guides as to be as good as barometers. There is no doubt but that the spiders, as well as the insects, give so good a general idea of the increase of temperature of spring that their reappearance is at all times worthy of observation. There is no doubt that the whole class is very susceptible of the return of genial weather; as Spallanzani has observed, their restlessness after so long an absence

from food, and their irritability due to their desire to lay eggs or propagate their kind, induces them to emerge from their hiding-places, at even a considerably lower temperature than that at which they hybernated in the previous autumn, thus becoming good (*Page* 63) indicators of alterations of the changes of the seasons. At the same time I do not attach much importance to the appearances of Trichocera hiemalis, as they may be observed all the year through, even in the depth of winter if the air be at all dry or quiet.

Ley, Rev. W. C. *Clouds and Weather Signs*, pp. 102–136. (B. 34). (*rv.*)

(*Page* 103) Aratus and Virgil would find themselves almost on a level with some meteorologists of the present day upon the subject of weather signs derived from cloud (*Page* 110) observations. The most valuable of weather signs are obtained not so much (*Page* 111) from the shape of the clouds as from the direction from which the clouds of different levels are observed to travel, and it is these weather signs which, in the present state of our knowledge, can be most readily reduced to definite rules. From the use of synchronous weather maps there has sprung up in recent years a new science of the winds. With the principles of this science all the more reliable rules of weather forecasting are most intimately connected. In judging of coming weather we invariably refer to rules already deduced from the long study of weather maps. The man who ignores these rules had better, in my opinion, leave all attempts at weather forecasting (*Page* 114) alone. The old observers were quite right in telling us that we know a great deal about coming weather from the appearances and forms of the clouds. They comparatively neglected the prognostics to be obtained from the movements of those bodies. We must give our attention both to form and movement, but more (*Page* 122) especially to the latter. The motions of cirrus clouds round depressions (*Page* 123) are of great importance in making forecasts of the weather, and in judging of the probabilities of storms.

Mann, R. J. *The Physical Properties of the Atmosphere.* In *Modern Meteorology*, p. 1–28. (B. 34.) (*rv.*)

(*Page* 1.) The word Meteorology is from the Greek term *μετέωρος*, which signified elevated or soaring. The name has not been adopted because meteorologists at one time busied themselves with observing falling stars. The word was used by Aristotle in very much the same sense as that in which it is now applied. In a treatise which he composed under the title Μετεωρολογικά, he dealt with all that was at that time known concerning water, air, and earthquakes. At the present time the object of meteorology is properly the scientific study of atmospheric phenomena and the investigation of weather and (*Page* 2) climate. The base of the science is therefore an exact acquaintance with the physical properties of the atmosphere.

Marié-Davy, H. (*B.* 35.)

[Describes the instruments at Montsouris.]

Marriott, Wm. (*B.* 36.) (*ra.*)

[Nothing for general notes.]

Meldrum, C. (*Nature*, xxi.)

(*Page* 167.) At any given place there are exceptions to every meteorological cycle. [Examples are given from temperature and barometric pressure.]

Moseley, H. N. (*B.* 57.)

[Nothing for general notes.]

P. (*B.* 60.)

[This is a misprint in 'The Scientific Roll.' It should be R.]

R. (*B.* 60.)

(*Page* 363.) Suggests that as carrier pigeons can fly 270 miles in less than six hours, they could be utilized for weather warnings by being despatched from outward-bound ships with weather news out at sea.

Scott, R. H. *The Nature, Methods, and General Objects of Meteorology.* pp. 166–186. (B. 34.) (*rv.*)

(*Page* 166.) Meteorology is the science of the atmosphere, of τὰ μετέωρα—the things (*Page* 167) above the earth—as Aristotle has it. It has even yet hardly made good its title to a place among the exact sciences. The reason of this is easily explained. Firstly, we live at the bottom of the atmospheric ocean, and of this the upper layers are all but inaccessible to us, so what half-knowledge we can gain of their condition is mostly derived from conjecture. We know really nothing of any phenomenon occurring above the level of the stratum which we inhabit. Secondly, the observations we make of the physical state of the air are affected to such a degree by local accidents, such as the elevation, contour, and slope of the ground, nay, even by the very character of the soil, that we meet with material variations of meteorological circumstances, even within the limits of a single county. In meteorology phenomena are not the same (*Page* 168) at two different points of observation. The temperature of the air and the motion of the wind in the street outside [Great George Street] differ appreciably from what is being experienced in the middle of Hyde Park, and *à fortiori*, from what is felt outside the city, as at Kew or Greenwich. Hence we see the necessity for covering the country with a network of independent meteorological stations for climatological purposes, as the observer at each place cannot do more than record the phenomena exhibited by the actual particles of the atmosphere which come in contact with his instruments. If we seek to investigate the climate of a thinly-peopled region, like one of our Australian colonies, we are thankful if we secure stations even 250 miles apart; but when we come to the consideration of our own climate at home we find that a distance of 50 miles is still too great to ensure that no special peculiarities shall escape (*Page* 169) our notice. In all this multiplication of stations we must not hold that quantity will in any way replace quality. The results from one bad station will often throw doubt on the figures of most conscientious observers. In more than one instance of recent times it has come out that results obtained by laborious calculations have been proved to be almost worthless, owing to the disregard in former times of obvious precautions to ensure accuracy in the observations and their registration. Good observers are required as well as good instruments, and good substitutes during the absences of the usual observers. (*Page* 178.) There are few recognized observatories of which the registers of uniformly high character go back for fifty years. The accurate records at each spot simply correspond with the period of office at the place of individual observers. When each died or left the place the chain was broken. If we find difficulty in securing accurate information for the climate of our highly civilised Europe, what are we to say about our knowledge of the climates of the other continents? This is scanty enough if we look for data of high scientific value. On a recent occasion our Secretary, Mr. Symons, published a valuable summary of the existing statistics of the climate of our colonies, but full as were the details in that paper, it showed us how much we have yet to learn before we can pretend to have gained a really comprehensive insight into the meteorological condition of the globe. The earliest systematic effort to obtain this information was the scheme organised in this country by the Committee of Physics and Meteorology of the Royal Society in 1840, and managed by Sir E. Sabine. A similar system was (*Page* 171) conducted in Russia under Kupffer. The results obtained at these colonial observatories have, in the few instances in which they have been discussed, thrown a flood of light on the condition of the atmosphere in widely different parts of the globe. It is a great pity that this system has not been continued. Of the four of our colonial

observatories only two, Cape Town and Toronto, survive. The Russians, however, have at all events maintained their stations. We are therefore compelled to admit that any accurate knowledge we possess of the meteorology of the globe is in a great measure derived from observations taken over a comparatively limited portion of the northern hemisphere. Still there is abundance of material in existence for any one who wishes (*Page* 172) to discuss it. Information from sea stations is wanted, but ships are seldom at rest. Hence we see the comparative fruitlessness of the attempts to deduce means of any value from the log of a single ship, no two observations having been made under exactly the same circumstances, except when she was at anchor. What we have to do is to take a definite area, say a one-degree square, in any part of the sea, and deal with all the ships which pass through it. Suppose that these ships have similar instruments and equally qualified observers, we are met at once by this difficulty. Suppose that this square really had seven days of easterly wind in each of two months, and that only one ship passed through in each of two months. A, bound to the eastward, would probably record twenty observations of the east wind as she would be beating against it, and detained in the square; while B, bound westwards, would fly through the square, and probably only put down the east wind twice. What is the true record of the wind for either month? C, again, may have been becalmed in the square for three days in an anticyclone, with his barometer ranging above 30·5 inches, while D, (*Page* 173) on another occasion may have been hove to in a winter gale with his barometer below 29 inches. In every one of these cases the local conditions will affect the observations taken, and any means obtained in their discussion. The problem is a tough one to solve, but we think that we have partially solved it for some small areas. The complication is even worse than I have described when we wish to deal with the climate of the sea at large, for we find that information cannot be got from unfrequented parts of the sea, unless ships are sent on purpose to get it. We see that in dealing with ocean meteorology it is nearly hopeless to look for a complete representation of the geographical distribution of meteorological conditions, and that no matter how carefully we collect and discuss our information, a large part of the isobars and isotherms which have been drawn over the sea are mere approximations. Still when we look at the great amount of meteorological knowledge which has been deduced from the logs of our marine observers, we take courage and feel that, although it may be long before absolute truth is obtained, we are yet bringing out valuable approximations for the use (*Page* 174) of the navigator, as well as for the physical geographer. There is another direction in which the subject of observing stations may be prosecuted, and of which the importance cannot be overrated, that is, the study of the weather. We may almost say that this is a new science, rendered possible by the facilities of communication afforded by the electric telegraph. This branch of inquiry demands heavy expenditure and a great amount of discipline and organisation, so that it cannot be prosecuted by individual observers, or at isolated stations. There is one broad feature of distinction between climatology and weather study as regards the collection of observations. In the former case we seek above all things for continuous records from the same spot. In the latter geographical position and freedom from conditions which will affect the character of the observations, especially of wind, are of paramount importance. If an opportunity occurs of obtaining a report from a new station which will give us earlier (*Page* 175) and surer intimation of coming changes of weather, we reject those from the most ably served observatory in the district. As regards synoptic work on a large scale, the importance of which to the meteorology of the future is being daily more and more acknowledged, it is evident that the records of the oldest established station are of no higher value than those of a ship on her rapid passage over the ocean. Here we boldly ask for more records, not from civilised countries, but from the unsurveyed world of Africa, Central Asia, Australia, South America, and our own North-West American territories. Meteorological processes go on whether men be present to register

them or not, and could we get it, a knowledge of what is going on at present over at least the whole northern hemisphere would be necessary for the complete elucidation of the agencies which produce our weather. We do not want more synoptic stations in these islands, for we have far too many already. At the present moment one good (*Page* 176) station on Spitzbergen or Jan Mayen would be worth ten in W. Europe. It is to be regretted that Wilczek and Weyprecht's far-seeing scheme of girdling the North Pole with a belt of observing stations, does not exhibit many symptoms of vitality. The methods of meteorological science are not by any means satisfactorily settled as yet. Some meteorologists decry all attempts of International Congresses to introduce uniformity of procedure and publication, while others insist upon uniformity to the regulations enforced in their own special organisation. The fact is great differ- (*Page* 177) ence of opinion and practice exist. The Russians call for siphon tubes; we prefer Fortin's or Kew pattern barometers. For thermometric exposure the battle of the screens is raging with its full fury. Minute accuracy in results is impossible with such wide difference of procedure. As regards methods, we are still in want of sug- (*Page* 178) gestions from experienced physicists. As regards hours of observation we are no nearer uniformity than our fathers were a generation ago. The ultimate uses (*Page* 184) of meteorology are twofold. Firstly, there is the strictly scientific (*Page* 185) use; and, secondly, its immediately practical use in the foretelling of weather. In marine meteorology we search for true mean values to indicate where a seaman may find a fair wind and a favourable current. There is not a profession, not a handicraft, not a process in animal or vegetable life, which is not influenced by meteorological changes, and there is not a human being to whom a knowledge of coming weather would not be of value. Had we a quarter of a century ago known the rigour of the Crimean climate, who would have dared to have sent out an army unprepared to meet the hardships of a Black Sea winter? Ask the physician at what price he would value the power of giving timely warning of a "cold snap" to his patients. Ask the builders of London what they have lost in the last ten years by sudden frosts or unexpected downpours of rain. Above all things go to the farmer, and ask what he would freely pay to know at seed time what weather he might really expect in harvest. The roll is endless—a knowledge of meteorology is of the very first importance in every stage of human life, civilised or uncivilised.

Strachan, Richard. (B. 34.)

(*Page* 73.) Readings of the Torricellian column [practically a barometer] were taken daily by Pascal at Paris, by Perrier at Clermont, by Chanut and Descartes at Stockholm during the years 1649–50 at the same time, in order to see if anything could be discovered by confronting them with one another. Pascal was thus the pioneer of (*Page* 78) synchronous observations. If it be admitted that every wind has its weather; then, to observe the direction and force of the wind is the first step to observe (*Page* 79) the weather. The practice has been to relate changes of wind and weather to the state of the barometer; and innumerable rules have been propounded to enable every-one to become weatherwise by the aid of the barometer. Torricelli began them, Pascal and Perrier added to them, Halley, Patrick, and Saul extended them. Something to do in this line was left to Dalton, Jenyns and Glaisher. I have not found a single rule among them. By rule I mean a mode of arriving at certain results from determinate conditions. They are all mere connotations of the weather with the heights and movements of the barometric column. When the behaviour of barometers in different regions and countries came to be known, these connotations were thrown into (*Page* 80) a little confusion. The latest connotators introduced some reasoning, especially Glaisher. He says: "It is the changes which constitute the barometer an indicator of approaching weather." Galton's charts, in his 'Meteorographica" (*Page* 85) (1863), were the earliest of weather-maps, and to him also we are indebted

for the main features of our daily weather-charts, lithographed as we get them by post. (*Page* 95) In 1859 Maury wrote that one of the great practical questions of the age was a daily system of weather reports between Europe and America. We have not accomplished this yet. The warnings sent by the 'New York Herald' are possibly based on information derived from ships arriving at New York, which enables it to telegraph the approach of storms before they have reached the coast of W. Europe. (*Page* 99) The law of pressure in relation to wind affords no means of foretelling weather by itself. Fixing attention on areas of pressure, either high or low, merely: the weather changes which attend them are only to be forecast by such data as their extent and gradient always, and either (1) rate and direction of progress; (2) rate of veering of the wind; or (3) rate of barometric change. The latter two may be either for one place or for several distant places. The problem has thus a variety of phases; but generally it may be stated thus. Given the barometric pressure, wind and weather at a place or region, at a definite instant, to estimate the change during a (*Page* 100) succeeding interval, as a day or two days. Either the translation of the air, the veering of the wind, or the change of pressure, must be assumed or known for the interval, and all the rest results as a matter of course. Barometrical observations appear to me to afford the most precise data for investigating the sunspot cycle as connected with the weather. There are no *a priori* reasons known to me for supporting that theory, and I consider the whole thing as a wild-goose chase. If it should be proved that the sunspot maximum coincides with a barometric minimum, and the sunspot minimum with a barometric maximum in India, there must be a region or (*Page* 101) regions where the law is the reverse; otherwise we should have to account for an abstraction from our atmosphere in some years, and an accession to it in others. The opinion of myself and most other meteorologists is that statistical results tend to show that there is a correlation between the meteorological elements considered either synoptically or statistically, that is to say, both in relation to geographical distribution as well as regard to a single station, and therefore it follows that the key to prediction is a foreknowledge of some one of them.

Symons, G. J. (*B.* 34.)

(*Page* 150.) In constructing a table of rainfall, there are two evils between which it seems necessary to choose. The longer the period of observation, the more trustworthy is the mean deduced from it, but if one is only to work up long registers, there (*Page* 151) will be large tracts of country without any. If one works with short registers, the means are liable to be in error through exceptional seasons not being adequately neutralised. I have adopted two ways of surmounting these difficulties. One is by taking first only the long registers, determining their true means, and the ratio which the fall in each year bears to the mean of the long period. Then by applying these ratios to the observations which were made for only a few years, one obtains a very close approach to the true mean for those stations. Another plan is to take several long registers, and to hunt through them for a short group of years, of which the average is nearly the same as the average of a long period. The great need (*Page* 165) of rainfall work, as of every other branch of meteorology, is neither more observations nor more money (though neither of these is to be despised), but more brains, more hard workers, more deep thinkers.

Williams, W. M. (*B.* 74.)

[He suggests that systematic observations be made on the variations of the Gulf Stream, with a view to obtaining forecasts of the coming season in W. Europe.]

Nature. (*B.* 80.)

(*Page* 514.) Dr. Gustav Hellmann reports on the meteorological organizations in the chief countries of Europe in the 'Journal of the Royal Statistical Bureau of Prussia' for

1878. He describes the systems in France, Great Britain, Belgium, and Holland. Diverse hours of observation are still practised.

Nature. (*B*. 81.)

(*Page* 381.) The monthly 'International Weather Chart of the Northern Hemisphere,' based on simultaneous observations, marks an important step in meteorological progress. It originates from the proposal at the Vienna Congress of 1873, that synoptic charts be formed, based on reports from Algiers, Austria, Amsterdam, Belgium, Great Britain, China, Central America, Denmark, France, Germany, Greece, Greenland, India, Italy, Ireland, Japan, Mexico, Morocco, the Netherlands, Norway, Portugal, Russia, Spain, Sweden, Switzerland, Turin, British North America, the United States, the Azores, the Sandwich Islands, Malta, Mauritius, the West Indies, South Africa, and South America. On July 1st, 1875, the daily issue of a printed bulletin exhibiting these international simultaneous reports was commenced at the Signal Office of the United States, and has since been maintained. It combines for the first time the work of nations for mutual benefit. A ship at sea becomes one of the best of stations for a simultaneous system. The value of the record is enhanced by the change in the ship's location every twenty-four hours. Every ship ought to carry meteorological instruments, both for its own sake and for that of others. The duty of observing requires but little effort. One hundred observations are made daily at sea. The average number of daily simultaneous observations now made in foreign countries [the remarks are from the United States Signal Office report] is 293. The total number of stations on land and on vessels at sea, from which reports are entered in the bulletins regularly, is 557. On July 1st, 1878, the issue was commenced of a daily international weather map. The charting embraces the whole northern hemisphere. The questions as to the translation of storms from (*Page* 383) continent to continent and of the times and directions they may take in such movements; the movements of areas of high and low barometer; the conditions of temperature, pressure, and wind direction existing around the earth at a fixed period of time, permitting thus the effects of day and night to be contrasted; the distribution and amount of rainfall and other studies, many and valuable, only suggested by this enumeration, may be by such studies settled. This simultaneous system enables studies by normals to be made. The inter-comparison of these normals with the normals taken at other places simultaneously with the first, and under the similar condition that the normals to be found for those places are from observations taken at those places at a fixed time and on every day, gives results reliable and different from those to be had by the use of normal readings arrived at in any other way. Normals for the year, for the season, and for the month may be determined by such procedure. The comparison of such normals will show, in the case of abnormal changes in any district or section for any season, whether and how they are compensated by compensating variations elsewhere. There are interesting studies as to what sequences there may be to follow such atmospheric variations occurring over any region or country—either in that region or country or elsewhere—and how and where the compensating variations occur, and with what concomitants or sequences of meteoric changes.

Nature. (*B*. 82.)

(Vol. xix. *Page* 232.) Professor Forster gave in on Dec. 22 a report on weather-warnings to the Bern Economical Society. He sketched the developments of these warnings in Europe and pointed out the importance of the *Service Agricole*, established between France and Austria, by which daily telegrams are sent advertising the coming weather: 85 per cent. of these prognostications have been perfectly true, 7 per cent. approximately true, and only 8 per cent. untrue. The first steps for the establishment (*Page* 236) of such a service has been made in Switzerland. Biot said, "It is in the high regions of the air that meteors are formed, rain, snow, and hail. There the

thunder rolls and the lightning traces its furrows. There are the upper currents which chariot the clouds. It is to these elevated regions that the inquiries of meteorological science ought to be directed. It has been recently discovered in France, by observations at Montsouris, that dust of various kinds is at most seasons of the year floating in the atmosphere, consisting of spherules so minute as to be discernible only by the microscope or by chemical tests; and that which so floats is not always the same in the higher as in the lower regions of the air." The bearings of this new information on epidemics affecting both animal and vegetable life is awakening much attention among continental physicists. High stations will furnish early intimation of changes in the weather. (*Page* 293.) In the article Atmosphere ('Encyclopædia Britannica') it has been justly remarked that one of the most important steps that could be taken towards the development of the science of meteorology would be an extensive series of observations from such countries as India, which offers splendid contrasts of climate at all seasons, has a surface covered at one place with the richest vegetation, and at others with vast stretches of sandy deserts, and presents extensive plateaux and sharp ascending peaks, all which conditions are indispensable for the solution of atmospheric physics. In working out this problem it is necessary, owing to its extreme complexity and difficulty, to give attention not merely to questions immediately bearing on the physics of the atmosphere, but to climatic and other practical inquiries which may be handled with comparative ease, and which afford results that contribute indirectly, but very materially, to the solution of the higher problem. The mean monthly pressure for each hour of observation is an essential requisite for the presentation of the data required in discussing various of the more important problems of international meteorology. The tables given by H. F. Blanford in 'Report on the Meteorology of India in 1876,' are entirely suited for the discussion of climatic questions of an international character, with the exception perhaps of the lumping of the wind observations into the monthly mean. (*Page* 329.) Professor Asa Gray (Amer. Journ. Sci.) takes it for granted that the indigenous plants of any country, particularly the trees, have been selected by climate. [Here and in the subsequent part of the article climate means temperature.] (*Page* 446.) A system of weather-warnings has been established in Switzerland. (*Page* 447.) The prognostics are correct in 8 cases out of 10.

(Vol. xx. *Page* 100.) (U. S. Nat. Acad., April 1879.) J. Weir Mitchell. 'The relation of Neuralgic Pains to Storms and the Earth's Magnetism.' (Meteorol. Soc. (*Page* 282.) June 18.) 'Report on the International Congress held at Rome, April (*Page* 434.) 1879.' By R. H. Scott. The Collegio Romano has issued, in a volume of 282 pp. (Rome, 1879), a French account of the Reports, &c., of the Congress at Rome.

1880.

Griffith, Rev. C. H. *Q. Journ. Meteorol. Soc.*, VI. No. for Jan.

(*Page* 21.) With a difference of more than three months in the recorded first appearance [of insects in s.w. England], but little can be gained in reference to the elucidation of facts in climatology. This difference may be due to want of an (*Page* 22) adequately systematic observation. The dates of none of the species are sufficiently well marked to hazard any remarks in consequence on climate; local influences are of course great, but I think they ought not to differ so much as they do.

Ley, Rev. W. Clement. (*B.* 9.) (*rv.*)

(*Page* 1.) The aids are intended for the use of observers in the British Isles [but many are applicable to other areas; and it is on account of the general principles (*Page* 6) involved that the remarks are here given]. Many of the weather signs relied on by shepherds and others whose occupations oblige them to be out of doors in all weathers, are extremely local, and the specially weather-wise men who rightly interpret

them in their own district would be quite at a loss if taken out of it and asked to form a judgment of coming weather in a different part of the country from the loc. l signs known there. Hence it is advised that all rules be mistrusted, and that inferences (*Page* 7) be deduced from well authenticated local signs. It is commonly said that a rosy sky at sunset presages fine weather, a red sky at sunrise bad, and a grey sky fine weather. This generalisation will be fallacious if applied as a rule, and inferences (*Page* 10) are not drawn as to the distribution of aqueous vapour in the air. The connection between barometric readings and the condition of the weather is not of a simple character. The several relations which constitute it must be patiently studied (*Page* 16) if we are to employ our knowledge usefully. Do the laws by which barometric fluctuations are governed fall under our cognisance? Are we acquainted with the special forms and contours of the variable areas of high and low pressure? Is their movement over the surface of the globe determined by conditions which we know? And, again, are they characterised by particular and definite states of weather in relation to temperature, state of sky, appearance of cloud, amount of rainfall and the like? It is obvious that on the answer to be given to these questions depends (*Page* 17) the whole status of our weather knowledge. If that answer were a simple negative this knowledge would scarcely be above the level of an instinct; in the place of rules we could have nothing but conflicting experiences. If, on the contrary, the laws of the atmospheric changes lay completely within the circle of our knowledge, weather wisdom might at once claim its place among the exact sciences; and it would be possible to establish fixed and definite rules, by the aid of which the observer could foretell coming weather with absolute certainty. If, however, as is the case, the truth lies between these extremes, if some of the conditions can be traced, whilst others are unknown, then weather wisdom is neither mere instinct nor an exact science, but a scientific art, containing both possibilities of instruction and elements of progress, and it becomes advisable to tread as carefully as possible through the border between knowledge and ignorance. Particular forms of cyclonic and anti-cyclonic areas are attended (*Page* 26) by their concomitant conditions of weather. The occurrence of secondary [barometric] disturbances is not unfrequently a cause of embarrassment to the observer who attempts to forecast wind and weather from local observations only. However, the weather which accompanies these phenomena has a somewhat distinct character of (*Page* 30) its own. There are a great many modifications of weather which depend on conditions either unknown or not as yet reducible to definite law or fixed classification. In a general way foul weather characterises the cyclonic and fair weather the anti-cyclonic systems, which corresponds to the old rule that the barometer falls before rain or storm, and rises before fine or calm weather. In the front of a large depression, at its extreme exterior that is to say, considerably outside of its isobars which form (*Page* 31) closed curves, there commonly stretches a great bank of cirro-stratus. The outside edge of this bank is pretty definite, and its outline in most cases is in rough correspondence with the contour of the advancing isobars. The movement of the upper current which carries the outlying parts of this elevated cloud bank is often nearly tangential to the edge of the cloud bank itself, and nearly opposite to the direction of the wind, which is presently about to spring up at the earth's surface, and in nearly all cases it makes a greater angle than 90° with this wind. It is important to observe that when this movement is very rapid the approaching depression may be expected to be deep and probably attended by strong winds at the earth's surface. As the sheet extends over us the upper current breaks very quickly, and continues to do so over the whole of the front half of the advancing system. As the centre advances towards us we commonly observe composite cloud (nimbus), the rain or snow being accompanied by the new current of air belonging to the depression. This cloud bank extends in most instances nearly over the front half of the system, both on the right hand and left hand of the centre's path, but its character differs very considerably

on the two sides. If the centre is passing so as to leave our station on its right, the nimbus usually continues until the centre has almost reached its nearest point to us. Then, usually after a sudden increase of precipitation, the sky clears, the cirro-stratus terminating in an abrupt line, while the wind at the earth's surface begins to veer, slightly if we are at a great distance from the centre, and greatly if we are near it. Up to this time the barometer will have continued to fall (except in those cases in which the whole system is becoming rapidly shallower) but the rapidity of the fall will have depended, as a moment's consideration will show, on four separate elements; the first, the rate of progress of the system; the second, steepness of its gradients; the third, the increase or diminution taking place at the time in this steepness, in other words, on the question whether the depression is becoming deeper or being filled up; and the fourth, on the distance of our station from the centre. Pressure now begins to rise (except in those instances in which the depression is becoming rapidly deeper). The appearance of the sky in the rear of the disturbance, but still on the right side of the centre's course, is usually very unlike that in the front. Comparatively few upper clouds are observed, and the movement of these is commonly observed to be nearly the same with that of the current on the earth's surface. In lieu of cirro-stratus we see fleecy cumulus. Shower clouds are also common over this district. These latter in summer, especially in our more inland regions, often take the form of local thunderstorms. In winter, passing squalls of rain, snow, and hail are common. Those on our western coasts are often attended by lightning. It should be remarked that these showers in the rear of a depression are far more extensive and persistent on exposed coasts and in hilly districts than in inland and more level countries. The atmosphere in this part of the disturbance (*Page* 32) is in most cases clearer, or more devoid of haze than in the front, and temperature is also commonly lower; but marked exceptions occur to both these rules. A rapid and excessive decrease of temperature is not uncommon when the wind has begun to veer, particularly near the centre of the cyclonic circulation. Now suppose the barometric minimum in its onward course to leave us on the left. Here the nimbus extends over us, the wind after springing up commences to back, and continues to do so throughout the passage of the disturbance. On this side we very rarely experience the abrupt change from a rainy to a clear sky which is so usual on the right-hand side. As the centre passes, the higher cloud forms gradually degenerate into banks of dreary stratus, often attended with an increase rather than any diminution of haze. As the rear of the system approaches us on this side the bolder forms of cumulus are rarely seen, and in place of the shower clouds we commonly notice gloomy-looking banks of condensed vapour in the middle and lower levels of the atmosphere, while cirrus has usually almost altogether disappeared. In the actual centre of a large depression the sky is often comparatively clear. Shower clouds are frequently visible, but these have usually here a thin soft and disintegrated aspect, while cumulus tends to spread itself into stratus, and cirrus lies in broken though watery-looking patches. The above description applies to the large and more important depressions; it cannot be applied without considerable modifications to the smaller or more local systems. These latter are more commonly characterised by more unbroken cloud banks, gloomy skies (often with rain or snow) prevailing over the central calm, and even to some extent over the extreme rear of the system. The secondaries are especially marked in most cases by very copious precipitation over the district which they traverse, the rainfall being usually greatly in excess of that which occurs over the rest of the primary disturbance. In summer, local depressions, especially if they are secondaries taking a northward direction, are usually associated with heavy thunderstorms. In the front of these last mentioned systems the cirro-stratus is commonly accompanied, and sometimes almost replaced, by the turreted stratus. The occurrence, therefore, of this form of cloud moving from some southerly

point over easterly or northerly surface winds is a valuable indication of approaching thunder showers. The weather which characterises anticyclones is in marked (*Page* 33) contrast to that which belongs to cyclones. It is, however, subject to far greater modifications in relation to the seasons of the year. In summer, and especially in our hotter summers, brilliant weather usually accompanies the anticyclonic circulations, the dry atmosphere permitting the sun's rays to exercise their full heating power on the stratum of air near the earth's surface. In the central districts, particularly, the sky is often nearly or totally devoid of cloud; at other times light fleecy cirrus, whose motion is extremely slow, is the principal cloud visible. Near the exterior of the system, especially on its eastern and south-eastern sides, stratus and fine weather cumulus, often accompanied by much haze, are the prevailing cloud forms. At the extreme western and northern borders cirro-cumulus and cirrus are very common, beneath which there is much fog occasionally at the sea coast, but rarely at the inland stations. Near the south-western limit of a large and well-formed summer anticyclone remarkably brilliant and cloudless weather often prevails. In winter the aspect of the sky in these systems is commonly different from that just described. Dry weather stratus is now the most common form of cloud, occasionally covering nearly the whole of the anticyclonic system with an unbroken canopy, the perpendicular thickness of which is very small, though its extent is so immense. Above this, in the higher region of the atmosphere, there is in such instances a remarkable absence of cloud; while beneath it dense ground fogs very commonly prevail at the inland stations. In some cases the sky is almost devoid of cloud, or the ground fog only prevails. In these latter instances the temperature is very low; whereas in the clouded anticyclone we usually experience only a moderately low temperature, the cloud layer checking the radiation. Near the exterior of the system the atmospheric currents usually break up, to a great extent, the canopy of cloud and land fog. On the eastern and south-eastern limits of the system the appearance of the clouds is often very similar to that which prevails in the same district of an anticyclone in the summer, but banks of the dry stratus are even here more common than true cumulus. It is usually in this district that the temperature is lowest in our islands, a fact that is due rather to our geographical position than to any other cause. Occasionally, however, we experience, as in summer, an exceedingly clear sky on the south-western side of a large anticyclone, which in winter is accompanied by an intense frost. It may be said generally that the occurrence in any marked degree of the dry weather stratus is commonly an indication of an anticyclonic movement of the air. Anticyclones are (*Page* 34) often nearly stationary for a considerable period. It is exceedingly difficult from observations made at a single station to foretell with anything like certainty the ultimate fate of a nearly stationary anticyclone, especially if the atmosphere be not only clouded but foggy. The following are specimens of forecasts taken from a weather diary.

1. Winter: in the rear, right-hand side, of a depression travelling to E. or N.E. Barometer moderately low, rising rapidly, brisk or moderate N.W. wind; clear sky between passing showers; very transparent atmosphere; no tendency to the formation of a bank of stratus; little or no cirrus. As depressions commonly follow each other in a series, and as the direction taken by the last, as well as the absence of the more anticyclonic cloud forms, indicates the absence of any anticyclone to the west, we expect the N.W. current shortly to fall calm, and to be followed by a fresh bank of cirro-stratus, decline of pressure, southerly wind and rain. 2. Winter; after a day or two of chilly W. and N.W. winds; depression in the north-east taking a south-easterly course. Wind W. or W.S.W., brisk or moderate; atmosphere mild; barometer about the mean or below it, falling rapidly; cloudy, with flying scud, rough looking composite cloud bank or dense cirro-stratus. The rapid decrease of pressure in conjunction with the aspect of the sky, and with the previous weather, makes it probable that the right hand segment

of a cyclonic circulation travelling south-eastwards is about to pass over the station; N.W. to N. or even N.N.E. gale is therefore to be apprehended, with a great fall of temperature and brisk recovery of pressure. 3. Summer: after moderately dry weather with westerly winds and barometer about or rather above the mean (northern limit of an anticyclone). Barometer about the mean and steady, or falling but little; wind S.W. or W.S.W., moderate or light; overcast with much low cloud. Temperature about or a little above the mean for the season. The right-hand portion of a depression taking a north-eastward direction is probably passing over the station; no rain, or (*Page* 35) but slightly drizzling showers, may be expected; the wind will most probably veer a little shortly with a clearer sky. 4. Winter: extreme rear, right hand of a large depression going E. or N.E. Calm, clear and cold: N.W. wind having died down and cumuli and shower clouds disappeared quickly, sheet of cirro-stratus on south horizon, edge travelling from W. or S.W.; barometer below mean, rising, but rise checked somewhat. If the new cirrus bank had appeared farther in the W. and its edge moved from a more northerly point, the fresh depression which is probably approaching might have been expected to follow nearly in the wake of the previous system. As it is, however, there is risk of its centre passing on the south side of the observer causing a temporary easterly wind, perhaps gale on exposed coasts, with overcast skies, and probably some sleet or snow. 5. Winter: after light winds and dull weather; barometer much above mean; totally overcast with low tranquil stratus, and nearly calm. As this is probably the central portion of an anticyclone no immediate change can be anticipated. 6. Summer: barometer near its mean level; falling somewhat; E. or N. breeze; turreted stratus above,—with some cirrus travelling rather briskly from a southerly point. A shallow depression is probably about to pass northward over the station; thunder and rain may be anticipated, followed by a light wind from some westerly point. 7. Summer: after westerly winds with temperature and pressure near the mean. Decided rise of barometer and very high temperature; extremely clear and brilliant sky with very few, and those only very low soft, clouds. Very light W. or N.W. breeze. The central part of an anticyclone, moving slowly north-eastwards, is likely to pass over the station. A further increase of temperature may be expected, followed probably by bright and hot easterly winds. 8. Winter: extreme rear of depression moving to S.E. Steady rise of barometer: wind veering from N.W. towards N.N.E.; hazy, with some dry-looking broken stratus, and no cirrus. An anticyclonic system may be surmised to exist over the W. or N.W. Fine and cold, though cloudy weather may therefore be expected with light winds. 9. Winter: after a period of disturbed weather, with cyclonic disturbances going eastwards. Barometer about or rather above the mean, scarcely falling; continuous calm for some hours, with persistent and rather heavy rains. The observer seems to be near the centre of a very shallow depression, whose course is not distinctly towards E. or N.E. There is therefore a probability that anticyclonic currents are forming in the north. Much drier weather, with a higher barometer, may consequently be with some probability anticipated.

Marcet, William. (*B.* 13.)

[Nothing for general notes.]

Marriott, Wm. *Remarks on the Winter of* 1878–9. *Trans. Watford Nat. Hist., II.*, pp. 237–240. (*ra.*)

[Refers to temperature at Greenwich and other places in England.]

Smyth, Piazzi. (*Nature*, xxi.)

(*Page* 249.) Weather predictions cannot be made years beforehand, owing to uncertainty as to the length of each sun-spot cycle.

Stewart, Balfour. (*Nature*, xxi.)

(*Page* 542.) The question of periodicity of rainfall may perhaps be solved by the method of deducing unknown inequalities proposed by Dodgson and myself. It consists in a way by which we may numerically estimate the indications of an equality. Let us suppose, for instance, that in ignorance of the diurnal range of temperature, we try to find whether there be a temperature inequality of 26 hours or of 24. We begin by taking a large number of hourly readings of temperature and group them into two series, the one containing 26, the other 24 numbers in a horizontal row. We should thus have 24 vertical columns for the one series and 26 for the other, and we should take the mean of each series as well as the mean of the whole. Now it would speedily be found that an inequality was indicated by the 24 hourly series and none by the others. The mean amount of the differences might be taken to form a numerical criterion of the presence or absence of an inequality. However, we must bear in mind that this method of detecting inequalities by summing up and averaging the departures from the mean caused by the inequality, likewise sums up and averages the accidental fluctuations. These accidental fluctuations can only be got rid of by a long series of observations.

Stewart, Balfour. (*Nature*, xxii.)

(*Page* 146.) There would appear to be a progress of magnetic phenomena from west to east, just as we know there is a progress of meteorological phenomena. As, however, the meteorological phenomena which we can examine occur in the lower atmospheric regions, while the magnetical phenomena are, according to my hypothesis, associated with currents in the higher regions, it does not follow that magnetic and meteorological phenomena should travel from west to east at the same rate. There is reason to believe that magnetic changes lag behind corresponding solar changes just as meteorological changes would do.

Nature.

(Vol. xxi. *Page* 316.) (Acad. Sci., Paris, Jan. 19.) Influence of climates on the maturation of corn, by M. Balland. [Refers to Temperature.]

(Vol. xxii. *Page* 229.) Vol. i. of 'Archives of the Deutsche Seewarte' contains reports on (1) Marine meteorology; and (2) Weather telegraphy and storm warnings.

(Vol. xxiii. *Page* 183.) The adequate discussion of the eight-hourly weather maps of the United States is the next great step to be taken in meteorology.

1881.

C., G. [probably George Clinch.] *The Weather. Monthly Nat. Hist. Notes*, vol. i. p. 8. Published in Jan. (*rv.* to date.)

[It refers to the advantage of trees being leafless during snow-storms and to temperature in England.]

Clinch, George. *Monthly Nat. Hist. Notes*, vol. i. Published in June. (*rv.* to date.)

(*Page* 51.) It is said that if the new moon be seen very early after the change rough and unfavourable weather is betokened.

Cordeaux, John. *Q. Journ. Meteorol. Soc.*, VII. Published in No. for Jan. (*ra.*)

(*Page* 47.) The character of the seasons appears to have very little effect on the regular migrating movements of birds. The swift seems even less under the influence (*Page* 48) of the weather than the swallow. With regard to the early or late nesting of birds as influenced by weather, the data are not sufficient to give any very reliable opinion.

Elsden, J. V. *Trans. Hertfordshire Nat. Hist. Soc.*, I. Read March 16, 1880. Published in March, 1881. (*ra.*)

(*Page* 111.) The drift exerts an indirect influence on climate. It is to the drift that we owe the well wooded appearance of our county. Trees exert a most important influence on climate by acting as frigorific causes. [Climate here then means temperature.]

Hazen, W. B. *American Meteorological Observations. Nature*, XXIV., p. 189.

[Explains why the Bulletin of simultaneous meteorological observations is published twelve, instead of six, months after date.]

Hopkinson, John. *Trans. Herts. Nat. Hist. Soc.*, I. Read April 20, 1880. Published March, 1881. (*ra.*)

(*Page* 138.) From the phenological observations made in Hertfordshire in 1879, it would appear that animals are not so much affected by the seasons as plants are.

M. R. I. A. (*B.* 8.)

(*Page* 411.) Granting (1) that solar periodicity produces a corresponding periodicity in any of the elements which make the climate of the earth, as a whole, what it is, and (2) that the expression for that change contains only the two first terms of the general expression, *i.e.* that there are no secondary . . . periods, both large admissions, it does not appear how a simple fluctuation of solar temperature recurring, we will say, every 11 years, could produce several periodic fluctuations of terrestrial temperature identical in duration but not simultaneous, some one or more being therefore partially or completely opposed in phase to some one or more of the remainder and to the causal fluctuation. Farther, we know that the sun-spot period is subject to large and seemingly capricious variation. If then solar atmospheric changes are reflected in marked variations in terrestrial climate, we shall find these latter to be common to the whole earth, and to be represented by a function of the same form. The mere citation of local (for in this connection even Europe may be regarded as local) phenomena which have occurred at intervals approximately equal individually to the average length of a sun-spot period proves nothing in favour of H. W. C.'s views; and an analysis of the data given by him which would make the occurrence of great frosts simultaneous, sometimes with sun-spot maxima and at other times with sun-spot minima, seems calculated to weaken his case in a material degree on the supposition of a uniform 11-years cycle.

Meldrum, Charles. [Circular relating to] Weather Charts and Storm Atlas in the Indian Ocean. Dated April 26.

It is generally admitted that simultaneous observations over wide areas are the best means for obtaining an insight into the laws of weather changes. Some persons consider that all that is required for ordinary seamen is a *résumé* of results. But to many others no statement of results can be so satisfactory as daily or hourly details presented in a graphic form. The mere enumeration of results for the benefit of practical men is not so much calculated to advance meteorology as a science. The highest authorities have recommended the synchronous method.

Meteorology. *Report of the Agricultural Meteorology Committee. Q. Journ. Meteorol. Soc.*, VII. Published in No. for April. (*ra.*)

(*Page* 102.) Q. 1. What are the mutual relations of the meteorological elements on vegetation; not only those which are proved to exist, but also those which are theoretically supposed to be practicable? A. Healthy vegetation depends on due proportion of warmth, moisture and light; in overcast and moist summers there is luxuriant

leafage and little flower; in sunny and dry summers leafage is moderate and flowering great (possibly no great amount of fruit, as the plants may be too much dried). These main points are much modified by circumstances that affect the ground temperatures; and these ground temperatures are of great importance, as through these, the flow of the sap may be retarded or entirely checked, or may be active in one part of the plant while it is exactly the reverse in the others, *i.e.* above or below ground as the case may be. The importance of this consideration is practically acknowledged by vine growers. The effect of a mild, overcast and moist summer and autumn or the reverse upon the ripening of the wood of that year and the fruit and leaf buds for the succeeding year is probably considerable, as also the effect on agricultural seeds, especially with regard to the cereal crops, as exemplified in the bread made from corn harvested in bad seasons (notably in 1839), drawing out into long sticky strings. Q. II. What observations of meteorological elements are to be particularly attended to with especial reference to their influence on vegetation? A. Sunshine; earth temperatures at depths not exceeding 4 feet; air temperature and range, humidity, wind, rain, and terrestrial radiation. Also solar radiation and evaporation, if satisfactory instruments can be obtained. Q. V. Can, at the present moment, meteorological central offices issue weather forecasts for the use of agriculture with reasonable prospects of utility?

Meteorology. *Resolutions adopted by the Conference for the Development of Agricultural and Forest Meteorology, held at Vienna in Sept.* 1880. *Q. Journ. Meteorol. Soc.*, VII. Published in No. for April. (*ra.*)

(*Page* 102.) Q. 1. [as before in previous paper.] Resolution:—

1. Vegetation is materially dependent on the following meteorological elements; (a) temperature of the air and soil; (b) duration and intensity of the illumination; (c) all the hydrometeors; consequently, the vapour tension and relative humidity, precipitation (rain, snow, etc.) as well as the other forms of condensation (fog, dew and hoar-frost); (d) motion of the air. On the other hand the daily march of pressure and of ozone appears to be of less importance for vegetation. 2. Conversely, the meteorological elements appear to exhibit the influence of vegetation in the following way. Vegetation on an augmented scale, such as pasturage, tilled land, forests and moorland, etc., give rise each in their own districts to special conditions of temperature and atmospheric humidity, and perhaps of rain also, and may therefore exert an influence on the climate of the surrounding country in respect of temperature and hydrometeors and also of springs.

Q. II. (as before, in previous paper.) Resolution:—

3. On the whole it appears important that on as many rationally managed estates as possible special observations should be carried on of all the elements recognised as important. These observations should be made in different soils, and with different types of culture, and should be compared with the crop return year by year, so as to investigate in detail the relation between vegetation and climatic factors. The general mean results published by the several central institutes do not furnish values in sufficient detail for the study of individual types of culture or of local conditions. [Then follow instructions in the method to be adopted for observing the various elements, with remarks on the trustworthiness of instruments, which will be given (*Page* 119) in connection with each element.] It is advisable to organise the system of radial stations in order to ascertain the effect extensive masses of vegetation, especially forests, exert on the climate of the surrounding region, both in their immediate vicinity and at a distance. This system promises better results the more continental is the character of the region in which it is established. Observations immediatedly above the tree crown are of importance. Q. IV. Would it not be desirable with a view to the special observations which must be undertaken (as, e.g., phenological observations) to prepare a general form of instructions? Resolution 23.

The Conference thinks it desirable to prepare general instructions for phenological observations. The list of plants to be observed should not be too long. They [members of committee] should deal in the first place with cereals and forage plants; secondly, with the more important forest and fruit trees; and lastly, with other plants of importance to agriculture and to the phenomena of animal life.

Meteorology. *Reports of Observatories. Q. Journ. Meteorol. Soc.*, VII. Published in No. for April. (*ra.*)

(*Page* 127.) In the wind charts for the region near the Cape of Good Hope the Meteorological Council of the Royal Society have adopted the principle of natural areas, that is to say, they have treated districts characterized by the same general conditions as wholes, and have abandoned the plan hitherto pursued of dealing with areas bounded by lines of latitude and longitude over which the same meteorological conditions might not prevail. The principle of natural areas has also been adopted by Prof. Buys Ballot, in his 'Maadelijksche Windkarte van der Noord Atlantischen Oceaan,' which appeared in 1878.

Rodwell, G. F. *Nature*, XXIV. (*rv.*)

(*Page* 32.) There are forty meteorological stations in the country extending from Mogador in Morocco to Sfax in Tunis. A daily bulletin has been issued since 1875, and it is distributed over thirteen points on the coast.

Stewart, Balfour. (*Nature*, xxiii.) (*rv.*)

(*Page* 237.) The evidence is strong in favour of some connection between the state of the sun's surface and terrestrial meteorology, while at the same time it is unmistakably indicated by all the elements that this connection is of such a nature as to imply that the sun is most powerful when there are most spots on his surface. The problem, Prof. Stokes points out, involves two questions. Firstly, do the changes which (*Page* 238) take place in the sun's surface correspond to changes in the meteorology and magnetism of the earth, and, if so, does an increase of spotted area denote an increase of solar activity or the reverse? Another question is whether these solar inequalities bear all or any of the marks of true periodicity. If they do not present true periodicity we cannot hope to predict the state of the sun. If they do present such periodicity we may gain such predicting power. Perhaps Mr. Chambers's method of prevision is not the best. Observations of the sun's intrinsic heat-giving power may perhaps be better.

Stewart Balfour. Lecture delivered at South Kensington, April 27. *Nature*, XXIV.

(*Page* 116.) The eleven-yearly oscillations of the sun's spots vary in magnitude. They were probably small about the middle of the last century, becoming large towards the end of it; they were again small about the early part of the present century. They have recently been large, and we may expect that in future there will be again a (*Page* 150) falling off. The sun is periodically stirred up, and being stirred up there is an increase in the light and heat which is radiated to the earth. This affects the meteorology of the earth.

Symons, G. J. *The History of English Meteorological Societies. Q. Journ. Meteorol. Soc.*, VII. pp. 65–98. Read Jan. 19. Published in No. for April. (*ra.*)

(*Page* 65.) The earliest English effort at forming a meteorological society, or at any rate, at securing observations made with comparable instruments, recorded upon a uniform system, was made in 1723 by Dr. James Jurin, in his address given in the Phil. Trans. for that year. On May 4, 1744, Roger Pickering read before the Royal Society a paper entitled, 'Scheme of a Diary of the Weather, together with draughts

(*Page* 66) and descriptions of machines subservient thereunto.' Pickering states that a sense of the importance of observing the weather induced Hippocrates, in his remarks upon the epidemic diseases in Thasos, to premise a general history of the weather preceding them; and with the same view did Boyle turn his thoughts so closely upon the same subject, whose example, being followed by others, both abroad and at home, has brought the natural history of the air to a surprising degree of perfection. The Royal Society commenced its register in 1774, but neglected it for several years after 1781. Daniell, in his 'Elements of Meteorology,' says the Meteorological Society (*Page* 67) of the Palatinate was established in 1780. One of the first acts of the Association was to write to all the principal universities, scientific academies and colleges, soliciting their co-operation, and offering to present them with all the necessary instruments properly verified by standards and free of expense. The offer was immediately accepted by thirty societies, and observations were made by Hemmer, Weis, Plann, Senebin, Bugge, Van Swinden, König, Catte, Egel, Pictet, Toaldo, and Euler. Hemmer sent ample instructions with the instruments. Some idea may be formed of the comprehensive scale of the register, when it is known that it contains observations three times in the day of the barometer, thermometer in the shade and in the sun, hygrometer, magnetic needle, direction and force of the wind, quantity of rain and of evaporation, the appearance of the sky, and in some places the electrical state of the atmosphere, and the presence of disease. The field of observation extended from the Ural Mountains in the east, to Cambridge in the United States in the west, and from Greenland and Norway in the north to Rome in the south, as also stations on three high mountains and on the summit of St. Gothard. The observations of each year are summed up and compared with those which precede in copious and most laborious tables of mean and extreme results. Hemmer died in 1790, and from that time the Society appears to have become extinct during the French revolution. Daniell says these volumes contain the first instances of representing barometric oscillations by a curve; but Dr. Lister was the true originator of this method. From 1781 to 1823 there was no uniformity, nor combination in the observations that were made. In 1823 (*Page* 69) J. G. Tatem proposed the formation of a Meteorological Society. A society was formed and its first meeting held, Oct. 15, 1823, and continued in existence till (*Page* 72) 1843, but very little work was done. Ruskin in his paper pointed out the necessity of the combination of simultaneous observations and the desire of the Society to know at any given instant the state of the atmosphere at every point of the surface.

Nature. (xxiii.) (*rv.*)

(*Page* 307.) (Meteor. Soc., Jan. 19.) G. J. Symons gave a history of Meteorological Societies from 1823 to 1880. The earliest English effort for securing observations made with comparable instruments upon a uniform system was made in 1723 by Dr. James Jurin. In 1744 another attempt was made by Roger Pickering, who read a paper entitled 'Scheme of a diary of the Weather, together with drafts and descriptions of machines subservient thereto.' The Meteorological Society of the Palatinate was established in 1780. In 1823 the first meeting of the Meteorological Society of London was held. The Society practically came to an end soon after 1841. In 1850–1851 the British Meteorological Society was established. The preliminary meeting was on April 3, 1850, the first general meeting on March 25, 1851. Annual reports were published from 1851 to 1861; then five volumes of Proceedings; then six volumes of the Quarterly Journal. The work of the Society is now so large as to require three computers.

Nature. (xxiv.) (*rv.*)

(*Page* 7.) Prof. Balfour Stewart, in his lecture at South Kensington on Solar Physics, stated his belief that one great cause of weather change is solar variability in

which we have periods of short length as well as others extending over many years. These weather changes are propagated from W. to E. The variations in diurnal declination of magnet are caused by solar variation and are propagated from W. to E., but more quickly than meteorological changes; hence it would seem possible that the magnetic weather of to-day may be followed by corresponding meteorological weather five or six days hence. Prof. Stewart has tried this and thinks that such is the case.

(*Page* 184.) Meteorol. Soc., June 15. The use of synchronous meteorological charts for determining mean values over the ocean by Charles Harding.

(*Page* 232.) Acad. Sci. Paris, June 27. On the prolegomena of a new treatise published in Italy by M. Diamilla Müller, by M. Faye.

[Refers to winds and atmospheric electricity.]

(*Page* 464.) Brit. Assoc. Meeting, Sept. The effects of gulf streams upon climates.

[Climates means temperature.]

ANNOUNCEMENTS.

The First Number of Part II. of the 'Scientific Roll' will be issued in May, 1882. This Part will deal with Aqueous Vapour. The Subscription for this Part is 2*s*. 6*d*., payable in advance to A. Ramsay. As the value of the Part will depend largely upon its degree of fulness, authors would materially aid in the work by sending copies of any papers they may have written bearing on the subject of aqueous vapour in its climatic relations; or, if they are unable to do this, by giving reference to their publications.

THE SCIENTIFIC ENQUIRER.

Correspondence is invited on Science matters of all kinds. In all cases, names and addresses should be given; but these will not be published without the writer's consent. The Conductor will not be responsible for the opinions expressed by Correspondents. All communications should be addressed to the Conductor, 10, *Bouverie Street, London, E.C.*

As no one has responded to this invitation, a few lines seem to be required to explain why it has been made, and to point out what are some of the possible advantages that may be derived from its acceptance. There are scores, nay, hundreds, of publications which devote more or less of their space to questions and answers for the benefit of their correspondents; and, therefore, it may be thought there is no need for another serial having the same feature, more especially one which appears so seldom as once a quarter, whereas most of the above are weekly or monthly. There is no intention here of holding out any promise for the future; but an attempt will be made to enhance the value of, and facilitate reference to, the subjects that may be dealt with in the correspondence by classifying the information as opportunity occurs. In this way, there will not be so much occasion for the repetition of the same question, and enquirers will be able to find whether any question has been asked more readily than is at present the case. and, if the question has been answered, where the information is given. It may be said that the indexes for the several serials answer this purpose. But considering that these indexes generally are not drawn up on any special plan, it frequently happens that the person consulting them does not hit upon the right key-word; and it seldom, if ever, is the case that the indexes are compiled in such a way that the consultor can draw a safe conclusion from what he finds that the information he seeks is definitely and inferentially implied to be absent in the work. In short, the purpose aimed at is so to systematise the matter as to make the references more easy, and to apply to queries the same principles as are developed in the 'Scientific Roll' with respect to facts. At some future time attention will be given to the classification of scientific workers, with a view to facilitate intercommunication between them. Should a plan of this kind be fairly well organised, questions will rarely fail to find their way to those most competent and willing to answer them.

ESSAY II.

ON THE CONNECTION BETWEEN SOLAR PHENOMENA AND CLIMATIC CYCLES.

By Prof. E. Douglas Archibald, M.A., F.M.S.

PART II.

(*Concluded from p.* 37.)

38. Besides the secular variations in terrestrial magnetism, there exist several other minor disturbances of magnetic equilibrium, many of which exhibit a periodic character corresponding not so much to the spots as to certain periods in solar and lunar motion. For example, Mr. J. Allan Broun from a long series of observations of the bifilar magnetometer (mostly at Trevandrum in Mysore) discovered a twenty-six day period which coincides very nearly with the period of the sun's rotation as indicated by Spörer, and subsequently an action upon the earth's magnetism which depends upon the relative position of the sun and moon with respect to the earth. It is at least significant to find that meteorological periods analogous to these, and through whose agency they are possibly caused, have already been observed. Mr. Broun himself found a meteorological period corresponding to the former of them; five years' observation of the barometer at Singapore all giving the period 25·74 days; while more recently Hornstein of Vienna has shown that the barometric pressure is so decidedly influenced by the aspect of the solar surface, that is to say, by the particular solar meridian which faces the place of observation, that the time of solar axial rotation can actually be approximately determined from observations of the height of the mercury column near the Equator.

39. It must, however, be remembered that different parts of the solar surface rotate with different velocities, the equatorial regions rotating faster than those near the poles. Herr Spörer found the mean period of the sidereal rotation of the entire solar surface to be 25·234 days, and Carrington 25·38 days; the synodic period would be about 1·7 days longer, and it is this period which is most likely to be communicated to terrestrial elements affected by the particular longitude of the sun presented to them.

40. Now there is some evidence that this synodic period is reflected in terrestrial temperature, and further, what is somewhat remarkable, that the sun-spots undergo a period of precisely the same length. Thus Nervander of Helsingfors in 1844 found from observations of the temperature at

Innsbruck and Paris a temperature period of 27·26 days. Dr. Buys-Ballot of Utrecht in 1851, employing observations from Dantzig, Haarlem, and Zwanenburg, found a temperature period of 27·682 days' duration, which besides being more carefully determined than Nervander's, coincides most remarkably with a sun-spot period of 27·686 days subsequently determined by Prof. Fritz of Zürich from Wolf's collection of observations of the sun-spots extending from 1612 to 1860.

41. These observations if they correspond to the synodic period would give for the sidereal mean period of solar rotation a length of 25·74 days, a quantity rather in excess of that given by either Carrington or Spörer. If, on the other hand, we examine the periods of somewhat similar duration determined by Broun and Hornstein for the variations of atmospheric pressure and magnetism, we find the former element gives us a length of 25·8 days and the latter one of 26 to 26·33[1] days for the synodic rotation. The sidereal rotation according to these results would be accomplished in about 24·13 days, a result widely differing from that derived from the temperature and spot periods.

42. It is possible, however, that we are here confronted by one of those too common obstacles to scientific progress, viz., an approximate coincidence of effects due to different causes. From a recent research of Prof. Balfour Stewart, a note on which was communicated to the British Association last year, it would appear probable that some of these short periods in the sun-spots, and therefore also in terrestial magnetism, are due to the conjunction of an intra-mercurial planet whose period is 24·011 days with the planets Mercury, Venus, and Jupiter respectively. If this surmise be correct, it is difficult to say whether some of the periods we have been considering are really due to solar rotation or to the synodic periods of this yet undiscovered planet. Thus assuming the period of this planet to be 24·011 days, which represents a sun-spot period of more than ordinary regularity, its synodic periods with the planets just referred to are as follows:—

With Mercury	33·025 days
With Venus	26·884 days,
With Jupiter	24·145 days.

corresponding to which Prof. Stewart has found the following inequalities in the sun spots:—

A very prominent inequality of period, 32·995 day.
A very prominent inequality of period, 26·871 days.
A less prominent inequality of period, 24·142 days.

The final confirmation of the planetary hypothesis would tend to settle the point as to whether there were any periods really dependent on solar rotation alone, but until this is accomplished it must necessarily remain somewhat doubtful.

43. Regarding the synodic periods of the moon with respect to the sun and earth, it has been found by Vice-Admiral Fleuriot de Langle that they are closely associated with corresponding variations in the number and

[1] Hornstein finds the latter period from observations at Prague.

intensity of hurricanes. This idea is, moreover, supported by the researches of Herr Schübler of Munich, M. Flaugergues of Viviers, and Herr Luedicke, who have all noted barometric changes corresponding to the varying relative position of the sun and moon of such a character as to agree with de Langle's results. It would further seem that the cause is in some way connected with gravity, since the changes in the moon's absolute distance from the earth are in like manner reflected in meteorological phenomena. Thus de Langle, on examining the particulars of one hundred and ninety-five hurricanes, found that one hundred and nine took place within three days of the moon's apogee or perigee, while Herr Luedicke found the greatest excesses and deficiencies in the height of the barometer to occur precisely at or near the same epochs.

44. It would seem, then, from the preceding remarks, that the sun and moon, by changes in the absolute distance of the latter from the earth, possibly by the rotation of the former on its axis, and by their relative position with regard to one another, exert marked influences not only upon terrestrial magnetism, but also upon terrestrial meteorology; so that in attempting to discover what periodical meteorological disturbances are in close connection with the peculiar molecular or thermal condition of the sun introduced by the presence or absence of spots, we must not lose sight of the fact that terrestrial weather is also decidedly influenced by—or at any rate affected contemporaneously with—the solar and lunar motions above mentioned. That these influences ever exceed those exercised by the spots is not very likely, but if they are present at all, they must tend to mask, or complicate, the effects produced by the latter.

45. Besides the magnetic changes which appear to be closely connected with corresponding meteorological changes, there are abrupt variations both in magnetic declination and horizontal intensity, accompanied very often by the Aurora Polaris, which appear to be communicated instantaneously to the earth without the intervention of a medium of meteorological disturbance. A well-known and often referred-to instance of this kind occurred in 1859, when a violent magnetic storm, accompanied by brilliant Boreal and Austral Auroræ, occurred coincidently with a remarkable outburst of magnesium over a sun-spot, observed simultaneously by Messrs. Hodgson and Carrington. Mr. Allan Broun found that some of these abrupt variations (generally diminutions of the earth's magnetism) are apparently connected with the period of solar rotation, following one another in many cases at intervals of twenty-six days or some multiple of twenty-six days and he hence inferred that the medium through which these actions are transmitted proceeds from the sun, is not uniformly distributed around it nor always distributed in the same way.[1]

46. It is evident, then, that in regarding the several cosmical influences at work upon the meteorology and magnetism of the earth, we must endeavour, as far as we can, to distinguish between those which produce

[1] 'Nature,' vol. xiii. No. 330.

magnetic disturbances indirectly through a medium of meteorological disturbance, and those which act directly upon the magnetism of the earth without the intervention of any such medium. Such influences, whether direct or indirect, may produce effects specifically alike. For while the Aurora Polaris and disturbances of the magnetic needle are phenomena often largely due to the influence of meteorological currents, and therefore exhibit a tendency to lag behind the corresponding meteorological changes; they are evidently at times affected instantaneously by disturbances in the physical condition of the solar surface (as, for example, the outburst of magnesium over a sun-spot in 1859 already referred to) as well as by the particular solar meridian which faces the earth (or by the possible intra-mercurial planet just referred to), since, according to Mr. J. Allan Broun, so many Auroræ accompanying the great magnetic disturbances repeat themselves at intervals of twenty-six days, when the same solar point returns opposite the earth.[1]

47. Electricity, in fact, is a form of energy which gives us little information regarding the proximate causes of its development in any particular case. It may be caused by almost anything in the shape of a disturbance, whether arising from heat, gravitation, tidal strain or friction, or inherent terrestrial and solar magnetism. Professor Adams attributes the magnetic periods corresponding to the relative position of the sun and moon with respect to the earth, to earth currents produced by alterations in the position of magnetic matter in the crust of the earth, caused by variations in the tidal pull of these bodies. The auroral disturbances he, in like manner, endeavours to show are produced by the friction between air and earth, due to atmospheric tides; but this hypothesis scarcely seems adequate to explain the abrupt disturbances of terrestrial magnetism, which so frequently coincide with solar storms and the Aurora.[2]

Professor Stokes, on the other hand, considers the earth currents to be secondary phenomena, and attributes the entire category of regular and irregular magnetic changes, and simultaneous appearances of the Aurora, to the action of solar radiation on atmospheric electricity, directly producing the Aurora, and indirectly thereby the earth currents which affect the needle. His idea, which was propounded in 1881, in a lecture on solar physics, delivered at South Kensington, is briefly this:—He conceives discharges of electricity, due to a horizontal difference of potential, to take place across the atmosphere at very high levels (especially at the level of minimum resistance, which, according to De La Rue's experiments, is about thirty-eight miles above the earth's surface) with corresponding return currents on the earth's surface. The former near the poles constitute the Aurora; and the latter the earth currents. When a solar storm, or an increase in the number and size of the spots occurs, the solar radiation is assumed to increase correspondingly, and so either the quantity of atmospheric

[1] Nature, vol. xiii., p. 329.

[2] Lecture delivered at the Royal Institution by Prof. W. G. Adams, Friday, June 3, 1881.

electricity, or the facility by which it may be discharged; the latter, as Professor Stokes says, possibly by the upper regions becoming relatively more heated than those below, and thus offering less resistance to the passage of the electric discharge.

48. This hypothesis of Professor Stokes's is something akin to one propounded by Professor Balfour Stewart, when delivering his presidential address before the British Association in 1875. He said: "It appears to be a tenable hypothesis to attribute at least the most prominent magnetic changes to atmospheric motions taking place in the upper regions of the atmosphere, where each moving stratum of air becomes a conductor moving across lines of magnetic force. . . . It thus seems possible that the excessive magnetic disturbances, which take place in years of maximum sun-spot, may not be directly caused by any solar action, but may rather be due to the excessive meteorological disturbances, which are likewise characteristic of such years. On the other hand, the magnetic and meteorological influence which Broun has found to be connected with the sun's rotation points to some unknown direct effect produced by our luminary, even if we imagine that the magnetic part of it is caused by the meteorological." Prof. Stewart therefore evidently thinks it probable that the *majority* of the magnetic disturbances which are referable to solar influence alone, are caused *indirectly* through an intervening medium of meteorological disturbance, which latter he assumes to be due to (1) the heat radiated by, and (2) a cyclone producing influence of, the sun. The specific distinction which Prof. Stewart so carefully draws between the two preceding influences seems scarcely necessary if we remember that, according to the views more recently entertained regarding cyclones, these phenomena merely represent disturbances due to either the condensation of vapour over a local area, or else a local difference of temperature, both of which are primarily due to solar radiated heat.

49. The hypotheses, however, of Prof. Stewart and Prof. Stokes agree in attributing the majority of the magnetic changes to a medium of meteorological disturbance, and this is important, because it shows us that if we find periods of magnetic disturbance, we have reasonable grounds for expecting to find some traces of analogous meteorological periods. The decennial period in terrestrial magnetism has long been an accepted fact, and it is beginning to be acknowledged that there is a similar period in meteorology. The longer periods in magnetism have likewise in all probability analogous periods in meteorology attached to them, and thus the one element may be used as a means of discovery for the other.

50. The general correspondence of some periods in magnetism and meteorology is exhibited in the following table:—(See p. 150.)

51. Since, notwithstanding the other influences already alluded to as introduced by the moon and planets, the most marked periods both in magnetism and meteorology, seem to be those dependent on the physical condition of the sun, we may conclude that cycles of weather are indeed

MAGNETISM.	METEOROLOGY.
(1) Solar diurnal variation.	(1) Solar diurnal variation in air-temperature, humidity, wind-force and direction, and barometric pressure.
(2) Lunar diurnal variation.	(2) Lunar diurnal tidal wave in the ocean, and probably also in the atmosphere.
(3) Variation corresponding to the period of lunar revolution, or the relative position of the sun and moon with respect to the earth.	(3) Similar period in storms (De Langle); height of barometric column (Luedicke); the relative frequency of Vesuvian eruptions (Palmieri [1]); and earthquakes (Perrey [2]).
(4) Semi-annual variation in the appearance of the Aurora Polaris, and disturbances of the magnetic needle, with maxima at the Equinoxes.	(4) Semi-annual variation in the number of cirrus polar bands, with maxima at the Equinoxes (Weber [3]); in solar and lunar halos (Tromboldt); in the frequency of gales throughout the world, and to a certain extent traceable in earthquakes.[4]
(5) 26 day solar axial rotational (?) or intra-mercurial planetary variation (Broun, Balfour Stewart, Hornstein).	(5) 26 day variation in the height of the barometer (Broun and Hornstein).
(6) Solar spot period decennial or undecennial (?) both in magnetic declination and horizontal force (Wolf, Sabine, Gautier, Broun, Lamont, Fritz). Similar period in the Aurora (Fritz, Loomis).	(6) Variation of same length in solar radiation (Blanford, Baxendell, and Hill); and in the numerous other dependent meteorological phenomena, such as air temperature (Köppen, Hahn, Fritz, Piazzi Smyth, Stone); rainfall (Meldrum, Lockyer, Hunter, Hill, and Archibald); vapour tension (Hill and Blanford); hail (Fritz); extension of glaciers (Hahn and Fritz); barometric pressure (Chambers, Hill, Blanford, and Archibald); cyclones (Meldrum and Poëy); wind direction (Main and Hornstein); cloud proportion (Schwabe, Hahn, Weber, Fritz); thunderstorms (Bezold, Fritz); and earthquakes (Kluge).[5]
(7) 55⅗ (55.6) year period in magnetic declination (Fritz); in the solar spots (Fritz and Wolf); and the Aurora (Fritz and Loomis).	(7) Similar period in the frequency of cyclones (Hahn); air temperature (Pfaff); and barometric pressure (Hornstein).
(8) 222 year period in magnetic declination (Kämtz, Moser, Kuppfer, Hansteen) and in the Aurora (Fritz[6]).	(8) No similar period as yet detected in meteorology, probably through lack of observations.

in close connection with solar phenomena; and that the day is not far distant when, armed with telescope, spectroscope, and, it may be, with still more powerful instruments of research, we may be able to predict with confidence, and for some time in advance, the mutations of the weather.

[1] 'Vesuvius,' by Phillips, p. 171.

[2] 'Force and Nature,' by Winslow, p. 478.

[3] Ueber die Beziehungen der Sonnen-fleckenperiode zu meteorologischen Erscheinungen Dr. F. G. Hahn, p. 128.

[4] 'Force and Nature,' p. 171.

[5] The variations in several of these elements do not directly follow those in the sun-spots, that is to say, their critical epochs are often reversed, as in the case of air temperature and barometic pressure. The important point is that the periods are equal in *length*.

[6] 'Zeitschrift für Meteorologie,' 1875, p. 31.

52. The general results of the investigations hitherto made into the relations between the shorter sun-spot period of approximately eleven years and the different meteorological elements may be briefly summed up as follows:

The temperature of the air is found to vary inversely with the sun-spot area, being higher than the mean in years of maximum sun-spot, and lower than the mean in years of minimum sun-spot. Fruit and wine, whose development depends on a variety of causes—temperature and rainfall being the chief—are found to vary in price according to the position of the year as regards the sun-spot cycle. In the present century fruit is found to be cheaper in years of maximum sun-spot. Wine is found to be subject to two variations, one in quantity, the other in quality. The maximum quantity occurs at the maximum epoch of sun-spot development, and the best quality occurs shortly after the epoch of minimum sun-spot.[1]

53. With some exceptions in the subtropical zone, probably more numerous than is at present imagined, the rainfall is greater in years of maximum sun-spot than in those at or near the epoch of minimum sun-spot. The rivers and lakes, as one would naturally suppose, are likewise found to be higher at the former epoch than at the latter. As rainfall constitutes an approximate measure of evaporation and thence of solar radiation, it would, if tested all over the world, probably afford a fairly correct estimate of the variation in solar heat at different times. It is certainly more trustworthy than air-temperature measured near the earth's surface, which, as Blanford has lately shown,[2] is largely affected by the amount of rainfall apart from the interception of the solar rays due to cloud.

54. Hail is found on the whole to occur more frequently in years of maximum sun-spot.

55. Regarding barometric pressure, one of the most important elements of meteorology, comparatively little has as yet been done; but Blanford's researches and those of Hill and F. Chambers in India have shown that barometric changes occur closely connected with those of the sun-spots. These changes, as might be expected in an element whose general sum total must remain tolerably constant over the earth's surface, vary in quality according to locality. Thus, so far, it has been found that over West Siberia the barometric pressure is lowest in minimum sun-spot years, and highest in maximum sun-spot years, while the contrary prevails over Indo-Malaysia. Traces of the same kind of compensatory variation have been found by the writer to occur between the west coast and the eastern central districts of Europe.

56. With respect to storms, it has long been known that the tropical cyclones occur most frequently in years of maximum sun-spot, while in the temperate regions the opposite apparently holds, at least as regards the

[1] The time of change from minimum to maximum sun-spot is only from three to four years and these are generally warm and dry in Europe, which probably accounts for the above fact.

[2] 'Journal of the Asiatic Society of Bengal,' vol. 50, part ii., 1881. 'On the Relations of Cloud and Rainfall to Temperature in India,' etc.

general movement of the air. It seems possible that in the years of minimum sun-spot the general motions of the atmosphere may be stronger, and therefore the sum total of the wind's velocity greater; while in maximum years we may have more violent storms, just as in the tropics there are more cyclones, the same cause operating in both cases, viz., a weakening of the general motions of the air at the maximum sun-spot epoch, which, by promoting the local aggregation of vapour, greatly facilitates the formation of cyclones.

57. Finally, the clouds are found to be generally more abundant at the maximum epoch of the spots, in this respect agreeing, as we should expect, with the variation in the rainfall. The particular variety of cloud called cirrus, associated by some with appearances of the aurora, is likewise found to prevail more at the same epoch.

58. When the relations between all these different elements are better known than at present, we shall be able to understand by what exact process (whether an increase or decrease of solar heat) the presence of sun-spots affects the conditions of the terrestrial atmosphere. At present we are considerably in the dark about the whole question; but nevertheless our gropings inevitably lead to the result that there *is* a most undoubted relation between solar phenomena and climatic cycles, and that this relation may be ultimately developed so as to become of the greatest scientific and economic value to the world.

EXPLANATORY REMARKS.—I.

Explanatory remarks will be given from time to time relative to the method of systematising notes.

On the present occasion it may be observed that the foregoing general notes represent a few books only, and are by no means a complete *résumé* of the literature. This is manifest if a comparison is made between the number of papers and volumes which are marked as having been read and of those which are not so marked. Hence it must be understood that any given statement assigned to a paper has some point of novelty only as regards the books that have been read.

A few repetitions may be observed, but some of them are intentional, while others are more so in appearance than in reality. The intentional ones arise from the facts being put in a different way, or from their having a different bearing. For instance, in the papers by Abercromby and Ley there are many facts in common, and a certain degree of consensus of opinion; but, as the papers have broad lines of distinction, it is necessary to repeat the facts in order to show their general bearing. Again, repetitions occur if the publications have been issued in the same year, because it often happens that it is difficult to ascertain which appeared first.

As an example of apparent repetitions may be instanced the passage in Buchan's 'Handy Book,' relating to the barometer and other instruments on page 3 of both editions. As there seems to be a slight difference the repetition is made; it being better to err by repeating than by omitting facts of this kind.

There is another point which requires explanation. Many of the statements are not general, but they have or may have a general bearing. It is impossible to enter these in the index as general facts, because the inference is made by reading as it were between the lines, and because no general application was intended by the original author; indeed, in some cases, such general application is expressly excluded. One example of this is seen at page 190 of Buchan's 'Handy Book' (N. 1867, B. 6). He says no prediction of the weather, at least in the British Isles, can be made for more than three days beforehand. Nevertheless the statement may be applied to a large part, if not the whole, of the world; although, as a general rule, Buchan's conclusions are chiefly based on observations in the British Isles. Again, at page 107, Alluard's observation of the barometer rising at one level while falling at another, is mentioned as showing the necessity of studying the atmosphere in vertical layers. This strictly refers only to barometric condition; but as this condition depends on other influences the remark has a much more general bearing. Care should,

therefore, be taken to distinguish between the actual statements made, and the broader meaning given to them by the position they occupy in these notes. Points of this kind are too subtle for any index to grasp them; and generally speaking they would escape notice in the original work.

SCIENTIFIC UNION.

We are indebted to Mr. John Hopkinson for the following account of the second annual conference of the delegates from scientific societies, held at York, on September 6, 1881. The undermentioned individuals were the delegates present on behalf of the Societies named.

Present:	*Society represented:*
W. Whitaker, B.A., F.G.S. *in the Chair.*	Norwich Geological Society.
David Grieve, F.R.S.E., F.G.S.	Royal Physical Society of Edinburgh.
Henry Muirhead, M.D.	Philosophical Society of Glasgow.
J. Barclay Murdoch, F.S.A., Scotland	Geological Society of Glasgow.
W. Ivison Macadam, F.C.S., F.I.C.	Geological Society of Edinburgh.
Isaac Roberts, F.G.S.	Liverpool Geological Society.
William E. A. Axon, F.S.S.	Manchester Statistical Society.
Raphael Meldola, F.R.A.S., F.C.S.	Epping Forest and County of Essex Naturalists' Field Club.
W. Denison Roebuck	Yorkshire Naturalists' Union.
John H. Gibson, M.D.	Hull Literary and Philosophical Society.
John Hopkinson, F.L.S., F.G.S. H. George Fordham, F.G.S.	Hertfordshire Natural History Society and Field Club.
Sir Walter Elliot, K.C.S.I., LL.D., F.R.S.	Berwickshire Naturalists' Club.
Rev. J. Magens Mello, M.A, F.G.S.	Chesterfield and Derbyshire Institute of Mining, Civil and Mechanical Engineers.
F. T. Mott, F.R.G.S.	Leicester Literary and Philosophical Society.
Rev. Joseph H. Thompson, B.A.	Worcestershire Naturalists' Field Club.
Thomas Lister W. E. Brady	Barnsley Naturalists' Society.
Rev. H. H. Winwood, M.A., F.G.S.	Bath Natural History and Antiquarian Field Club.
W. Pengelly, F.R.S.	Devonshire Association for the Advancement of Science, Literature, and Art.
Professor H. G. Seeley, F.R.S.	

The Minutes of the Conference held at Swansea, August 31st, 1880, were taken as read, confirmed, and signed by the Chairman.

The Report of the Committee appointed at Swansea, consisting of Mr. John Hopkinson and Mr. H. George Fordham, was read as follows:—"We have to report that we have issued to all the scientific societies in the United Kingdom entitled to send delegates to the British Association, a report of the conference at Swansea, and a circular-letter inviting these societies to send delegates to the York meeting, and that in connexion with

this we have been engaged in a considerable amount of correspondence. We have also to report that in order to place these conferences on a firmer basis than could otherwise be done, and to meet the necessary expenditure, we have proposed the appended resolution; that this resolution has passed the committees of Sections A, C, and D; and will be brought before the Committee of Recommendations this day:—'That a committee be appointed, consisting of Sir Walter Elliot, F.R.S., Mr. H. George Fordham, Mr. John Hopkinson, Mr. G. J. Symons, F.R.S., and Mr. W. Whitaker, to arrange for a conference of delegates from scientific societies to be held at the annual meetings of the British Association, with a view to promote the interests of the societies represented by inducing them to undertake definite systematic work on a uniform plan; that Mr. Fordham be the secretary, and that the sum of £5 be placed at their disposal for the purpose. (Signed) John Hopkinson, H. George Fordham."

The adoption of the Report was moved by Dr. Gibson, seconded by Mr. Roberts, and unanimously agreed to.

A discussion of the general objects of the Conference and its future work ensued, in which Sir Walter Elliot, Messrs. H. G. Fordham, W. E. A. Axon, Thomas Lister, F. T. Mott, the Rev. J. M. Mello, and others took part.

Mr. John Hopkinson gave an account of the operations of the Hertfordshire Natural History Society, referring especially to the large number of members who were undertaking the registration of the rainfall; the recording of periodical natural phenomena, such as the time of flowering of plants, the appearance of insects, and the arrival and departure of migratory birds; and also the preparation of lists of the fauna and flora of the county. He felt sure that if the Secretaries of Natural-History Societies generally, would induce the members of their Societies to undertake such work, in which all could take part, not only would science be advanced, but a greatly-increased number of members would take an active and permanent interest in their Society; and to further this end he suggested the preparation and issue, by a committee of the Conference, of instructions to observers in these and other departments of science.

Mr. H. G. Fordham suggested that the local societies might, from their special local knowledge, and from the fact of their being able to obtain the assistance of a great number of observers scattered over large areas of the country, afford help to the committees appointed by the British Association on such subjects as luminous meteors, the circulation of underground water, erratic blocks, and rainfall.

Sir Walter Elliot doubted whether very much of this work could be done by the local societies, but the operations sketched out by Mr. Hopkinson were practicable and useful, and he had advocated similar work in Berwickshire years ago.

Mr. Axon said that the Conference would be doing a real service to science if they could induce the local societies to take up such work, and also utilise by systematic record the many observations that were being

made throughout the country, and which at present were largely wasted, and

Mr. Thomas Lister mentioned that as a result of last year's Conference, the Barnsley Society had begun to print Transactions.

It being understood that the Committee of Recommendations would most probably not accept the resolution mentioned in the report just read, it was moved by Mr. Roberts, seconded by the Rev. J. M. Mello, and unanimously resolved:—"That the gentlemen named in the resolution appended to the report take steps to have the Conference of Delegates recognised by the Council of the British Association."

In order to meet the necessary expenses entailed by printing and issuing the circulars ordered to be sent out by the Conference, it was agreed that 5*s.* be subscribed by each delegate present, and the sum of £3 10*s.* was handed over to the Committee. Further contributions are asked for; and may be forwarded to Mr. H. George Fordham, Odsey Grange, Royston.

A resolution was then moved by Mr. Fordham, seconded by Mr. Mott, and agreed to:—"That it be an instruction to the Committee to send out a circular to the various Local Scientific Societies, pointing out the work undertaken by the Committees of the British Association, and the valuable aid which may be given by these Societies in that and other scientific work."

A vote of thanks to the Chairman closed the proceedings.

The annual conference of delegates from scientific societies is so entirely in accordance with the objects which the 'Scientific Roll' seeks to promote that we willingly give it our heartiest support, and strongly urge upon all scientific societies the advantages which would accrue to them as well as to science by their sending in their adherence to it.

The discovery of laws and a foreknowledge of the progress of events is to a certain extent facilitated in proportion as individual efforts are directed by systems which have been adopted as the result of conference between all the observers, either directly or indirectly by means of delegates. There are many ways by which these individual efforts can be directed; but it is not our intention at present to make any detailed suggestions. One of the most practical of those proposed above is the issue of instructions on special questions or lines of inquiry. These instructions should in each case be accompanied by a well-considered set of questions drawn up by some specialist, revised by a committee, and then amended by the person who originally drew up the questions. If these sets of questions were submitted to all the local societies, some useful results would be obtained.

Great advantages would be derived from the extension of the system of registering natural phenomena according to a generally adopted plan. As an example we would refer to the rainfall system of observation organised by G. J. Symons. This system, which is admirably conducted, is beyond the energies of the most willing worker. In the case of a few counties,

such as Berkshire and Hertfordshire, individuals have undertaken the superintendence of the observers as well as the collection and discussion of the data. This is a help so far, but still more help would be rendered if every county had similar superintendence. It surely would not be a difficult matter to organise a complete system of rainfall superintendence for every part of the British Isles.

Other branches of science could be taken up as opportunities offered; until by persistently pursuing the same plan there would be built up a completely organised system of scientific observation equally adapted for continuous records, and for special enquiries demanding attention for periods of time of variable length.

We would also recommend the compilation of a classified directory of scientific workers; and we should be glad to carry out the recommendation by receiving the names of persons with particulars as to their special scientific pursuits. If complete enough, selections from it would be published.

THE SCIENTIFIC ENQUIRER.

Correspondence is invited on Science matters of all kinds. In all cases, names and addresses should be given; but these will not be published without the writer's consent. The Conductor will not be responsible for the opinions expressed by Correspondents. All communications should be addressed to the Conductor, 10, *Bouverie Street, London, E.C.*

As no one has responded to this invitation, a few lines seem to be required to explain why it has been made, and to point out what are some of the possible advantages that may be derived from its acceptance. There are scores, nay, hundreds, of publications which devote more or less of their space to questions and answers for the benefit of their correspondents; and, therefore, it may be thought there is no need for another serial having the same feature, more especially one which appears so seldom as once a quarter, whereas most of the above are weekly or monthly. There is no intention here of holding out any promise for the future; but an attempt will be made to enhance the value of, nd facilitate reference to, the subjects that may be dealt with in the correspondence by assifying the information as opportunity occurs. In this way, there will not be so much asion for the repetition of the same question, and enquirers will be able to find whether y question has been asked more readily than is at present the case, and, if the question has been answered, where the information is given. It may be said that the indexes for the several serials answer this purpose. But considering that these indexes generally ar not drawn up on any special plan, it frequently happens that the person consulting ther does not hit upon the right key-word; and it seldom, if ever, is the case that the indexe are compiled in such a way that the consultor can draw a safe conclusion from what h finds that the information he secks is definitely and inferentially implied to be absent fr the work. In short, the purpose aimed at is so to systematise the matter as to make th references more easy, and to apply to queries the same principles as are developed in the 'Scientific Roll' with respect to facts. At some future time attention will be given to the classification of scientific workers, with a view to facilitate intercommunication betw them. Should a plan of this kind be fairly well organised, questions will rarely fail find their way to those most competent and willing to answer them.

ANNOUNCEMENTS.

The First Number of Part II. of the 'Scientific Roll' will be issued in May, 1882. Thi Part will deal with Aqueous Vapour. The Subscription for this Part is 2*s.* 6*d.*, payabl in advance to A. Ramsay. As the value of the Part will depend largely upon its degree o fulness, authors would materially aid in the work by sending copies of any papers the may have written bearing on the subject of aqueous vapour in its climatic relations; or, they are unable to do this, by giving references to their publications.

INDEX.

THE Index to the present part is only a subject index. The Conductor would have desired the addition of indexes of persons, places, and time; but as these would occupy more space than it seems advisable to allow, he has not ventured to give them. If there should be any call for such indexes an attempt will be made to supply them. From the nature of the notes many cannot be referred to in the index. And as regards the index itself, it is to be noticed that it is a tentative effort to base the entries on the subject of the papers rather than upon catchwords occurring in the titles. There are, doubtless, many errors and defects; but while there is no intention to make any excuse for these, still it may be observed that difficulties are often caused by the indefinite, or rather ill-defined, nature of the titles. These difficulties are, however, just the same whether catchwords are or are not used.

CONTRACTIONS.

Int = Introduction. E = Essay. Re = Remarks. B = Bibliography. N = Notes. The figu[r]
immediately following these contractions indicate the numbers of the paragraphs in the case of t[h]
Introduction, Essays, and Remarks; in the case of the Bibliography they denote the year a[n]
number assigned to each item; and in the case of the notes the pages of the original. The referenc[e]
to the pages of the 'Scientific Roll' are always preceded by p. and are always placed first.

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ERRATA.

The lines are reckoned from the top.

p. 11, col. 2, line 25. For 2 read 3.
„ „ 29. For 3 „ 4.
p. 12, col. 1, line 10. For *une* read *und.*
„ „ 33. Add Gilbert, Annalen, xiv. p. 348–363.
„ col. 2, line 23. For *Vassalli, Eaudi* read *Vassalli-Eaudi.*
p. 13, col. 1, line 37. For *meorologischen* read *meteorologischen.*
„ col. 2, lines 6, 16, and 33. For *Osservazione* read *Osservazioni.*
p. 14, col. 2, line 10. For 6 read 7.
„ „ line 14. For 7 read 8.
p. 16, col. 1, line 29. For *phenomena* read *phenomenon.*
p. 18, line 12. For *is* read *so.*
p. 39, col. 2, line 66. For *Davld* read *David.*
p. 41, col. 2, line 7. For 253 read 353.
p. 42, col. 1, line 64. Add . 74–85.
„ col. 2, line 38. For *Sci* read *meteor.*
„ „ line 55. For 4 read 8.
p. 45, col. 1, line 21. For *David Alloys* read *David, Aloys.*
p. 46, col. 1, line 31. For 8 read 10.
„ „ line 58, col. 2, line 38. For *Ass.* read *Asi.*
p. 49, col. 2, line 44. For 1851 read 1855.
p. 51, col. 1, line 45. For 1856–7 read 1856, 3.
p. 51, col. 1, line 47. For 7 read 9.
p. 52, col. 1, line 32. For *Jena* read *gera.*
„ „ line 42. For *Edouard* read *Edward.*
p. 55, col. 1, line 23. For *Daubeney* read *Daubeny.*
„ col. 2, line 58. Insert *experimental* after *An.*
p. 58, col. 2, line 24. For 656 read 646.
p. 63, col. 1, line 25. For *T. D.* read *D. T.*
„ col. 2, line 45. For 1870 read 1870, 23.
„ „ line 58. For *iv.* read *v.*
p. 65, col. 2, line 10. For *Woeikof* read *Woeikoff.*
p. 68, col. 1, line 60. For *The Weather Report* read *The Weather. Report*
p. 71, col. 2, line 56. For *xvii.* read *xvi.*
„ „ line 59. Insert *Soc.* after *Roy.*
p. 73, col. 1, line 26. Delete *J.*
p. 74, col. 1, lines 47, 51. For *Hellman* read *Hellmann.*
p. 75, col. 1, line 47. For *P.* read *R.*
p. 76, col. 1, line 30. For *Ann.* read *Am.*
p. 78, line 16. For 112 read 212.
„ line 22. For 4 read 1.
p. 80, line 28. Insert *view* after *bird's eye.*
p. 88, line 36. For *Well's* read *Wells's.*
p. 100, line 32. For *J.* read *T.*
p. 119, last line. For *procees* read *process.*
p. 123, line 26. Insert *as* after *is.*
p. 124, line 18. For *Meyer* read *Myer.*
p. 126, line 40. For *Valenita* read *Valentia.*
p. 140, line 51. For *immediatedly* read *immediately.*

AQUEOUS VAPOUR: REMARKS.

UNDER this head will be grouped facts relating to the geographical distribution of aqueous vapour, both that which is invisible and that which is partially condensed, as in clouds, fogs, mists, dew and kindred phenomena. The properties will be given under Water, not under Climate, except in a few cases for the purpose of explaining climatic phenomena. The aqueous vapour notes also deal with other points, such as the absolute amount of aqueous vapour in the atmosphere, the humidity or degree of saturation, and the variation of both these with height above the sea and the ground, season, and period of day. They also take into account discussions as to the rate of evaporation according to circumstances, and clouds. The notes further embrace facts relating to all the causes which modify the amount and rate of variation of evaporation, such as areas of water, nature of ground, whether covered with vegetation or not, and other collateral matters. Plants and animals in many cases afford some indications of the state of the air of a locality as regards moisture, and hence facts relating to these which seem to have a bearing on the subject are admitted here.

The explanation of the contractions for the various periodicals and books will be given when the first volume has been completed; the following, however, may be mentioned here. Every item, whether it be a paper, or a volume, or a series of volumes, which has been examined, and the facts afforded by it placed in the magazine, is marked *ra*, if the article only has been read; *rv*, if the volume has been analysed; and *rs*, if the series has been searched; but when such item has been perused too late for the insertion of the facts in their proper place in the previously published portion of the magazine, *p* is appended to these. In this case they become *rap*, *rvp*, or *rsp*. These unpublished entries are entered in the manuscript notes, and will be available for the next edition. The date following the number of the volume in parentheses, is the date given on the titlepage of the volume. In the case of serials the separate numbers were published earlier. When the dates of these are known the notes are entered under the year of publication of the number.

The bibliography for the years 1875 and onwards is deferred in order to allow of publishers and authors sending in copies or notices of their more recent publications which relate to the subject of the present part.

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AQUEOUS VAPOUR: NOTES.

1682.

Hobbes, Thomas. (*B.* 1682, 1.)

(*Page* 26.) It is by the motion of the sun that fluid bodies are made to exhale out of the earth.

A. 'Tis very probable that the same action of the sun is that which from the sea and moist places of the earth, but especially from the sea, fetcheth the water up into the clouds.

(*Page* 45.) A. What is the original cause of rain?

B. The motion of the air, tending to the disunion of the parts of the air, must needs cause a continual endeavour of whatsoever fluids there are upon the face of the earth and sea to supply the place which would else be empty. This makes the water, and also very small and loose parts of the earth and sea, to rise and mingle themselves with the air, and to become mist and clouds, of which the greatest quantity arise there where there is most water, namely, from the large parts of the ocean: which are the South Sea, the Indian Sea, and the sea that divideth Europe and Africa from America, over which the sun for the greatest part of the year is perpendicular, and consequently raiseth a greater quantity of water, which afterwards gathered into clouds falls down in rain.

A. If the sun can thus draw up the water, though but in small drops, why can it not as easily hold it up?

B. It is likely it would also hold them up if they did not grow greater by meeting together, nor were carried away by the air towards the Poles.

A. What makes them gather together?

B. It is not improbable that they are carried against hills, and there stopt till more overtake them. And when they are carried towards the north or south, where the force of the sun is more oblique and thereby weaker, they descend gently by their own weight. And because they all tend to the centre of the earth, they must needs be united in their way for want of room and so grow bigger, and then it rains.

(*Page* 56.) A. What breaketh the clouds when frozen?

B. In very hot weather the sun raiseth from the sea and all moist places abundance of water, and to a great height. And while this water hangs over us in clouds, or is again (*Page* 57) descending, it raiseth other clouds, and it happens very often that they press the air between them and squeeze it through the clouds themselves. [He seems to have no idea of vaporisation. The essay is in the form of a dialogue, the interlocutors in which are called A and B.]

1766.

Saul, Rev. Edward. (*B.* 1766, 1.)

(*Page* 16.) Boyle proved that the pressure is least when the air is most charged with (*Page* 26) clouds and vapours. It has been suggested that the difference in the air's gravity proceeded from its being more or less charged with vapour. If this were the cause of it there must be as much vapour in the air at a time as is equal to the weight of 3 inches of mercury; for so much do we commonly find the mercury to rise and fall. Consequently the vapours in the air at once will be equal to the weight of a column of (*Page* 27) water 42 inches in height, which is not only incredible but exceeds a year's

rainfall [in England]. The reason, then, why the air is heavier at one time than another, cannot be from the quantity of vapour floating in it. When the air is heavy (*Page* 29) the vapours rise with the greater ease, and continue supported in larger quantities at a greater height from the surface of the earth. And this exhalation proceeds partly from a subterraneous heat streaming out from the centre of the earth raising (*Page* 30) sometimes a sensible steam, but chiefly from the rays of the sun, which, falling obliquely upon the surface of the water, and being, many of them, reflected back with minute aqueous particles adhering to them, or thin watery cases surrounding them, are by that means supposed to raise copious and continual exhalations from them. These vapours being rarefied to a great degree, and (as Dr. Halley and Mr. Derham imagine) formed into real but imperceptible bubbles by the heat, and actuated by the rays of the sun, grow specifically lighter than the air, and consequently must rise till they come to an air of the same specific gravity with themselves, where they (*Page* 31) will rest. And thus in proportion to the weight of the air and the density or rarefaction of the vapours themselves they will either float near the surface of the earth under the appearance of mists or fogs, or else, mounting up out of sight they will range themselves in higher or lower regions of the atmosphere, suitably to their specific gravity, where they will rest. And if at any time during their suspension the state of the atmosphere varies by any attenuation or compression in the regions above, the situation of the vapours will in like manner range with it, either by a further ascent upwards or depression downwards according as the weight of the atmosphere is increased or diminished. It is only of these steams, mists and vapours thus raised from the surface of the earth and sea, thus carried up and supported at different heights, thus floating in seemingly large compacted bodies, and those confusedly driven together and accumulated by the winds, that the clouds are formed; which are in reality no other (*Page* 32) than exalted mists ranged above in higher or lower horizontal planes in proportion to the comparative density or rarefaction of the vapours themselves with that (*Page* 33) of the atmosphere wherein they are buoyed up. Such vapours as are raised up by the declining sun or hang near the surface of the earth, being condensed by the coldness of the nights, in the summer fall back as dews, and in the winter as hoary (*Page* 34) frosts. In what we call a black frost either the rise of the vapours is quite intercepted or rather they are raised too high to be reached and precipitated by the cold (*Page* 36) below. When the wind turns the stream of clouds and vapours one way it (*Page* 37) soon clears the hemisphere [=atmosphere]. The dryness of Peru and Chili may be ascribed to the accumulation of air there, the winds accumulating the air on the west (*Page* 38) side of the Andes. It is to an extraordinary attenuation of the air that we ascribe the sudden overcasting of the sky, when in a calm, sultry morning, without any visible clouds arising from below the horizon, a clear hemisphere (by the descent of the vapours into the lower regions of the air) unexpectedly becomes hazy, thick and cloudy, (*Page* 42) and even sometimes misty and rainy. In misty or foggy weather (if it be of any continuance) the glass is commonly observed to stand very high; because the air is then usually still and presses with its full perpendicular weight. Dr. Wallis is of opinion that the mists and vapours hanging thus in the air add to its pressure, which no (*Page* 43) doubt is true in general, because the collective body of the air and vapours taken together must weigh more than the air alone. And upon this account n ot on in misty, but in dark settled calm weather (when the vapours are raised and supported at a very great height; and so equally and copiously dispersed that the sky appears uniformly thick and hazy in all quarters; without the least gleam of sunshine breaking through or any cloud distinctly formed), in such a dense state of the atmosphere the weight of it is greatly increased, and the height of the mercury is usually near 30 inches. But as soon as this state of the atmosphere changes either by the wind rising, the sun breaking out, or both together dispersing the hemisphere [canopy] of vapour, and forming many of them into large clouds sailing above, the mercury will in a few

hours settle to 29½ inches, and sometimes to 29 inches. Hence it is observable that the general and equal distribution of the vapours, whether in mists below or in a hazy sky above, acts with a greater degree of pressure than any partial or unequal distribution of (*Page* 44) them in clouds, which, whether suspended in the air or moving horizontally, interrupt and take off some part of the perpendicular pressure from the regions above. That (*Page* 45) the clouds do lessen the weight of the air seems proved by the following experiments by Boyle. A piece of sponge suspended in equilibrio in sunshine becomes heavier when a cloud passes over, but returns to equilibrium when the cloud has passed. (*Page* 46) Boyle cites this as a proof of humidity, but it really indicates a decreased (*Page* 47) heaviness in the air. Dr. Wallis accounts for the gradual sinking and lowness of the barometer in rainy weather by the air getting lighter in proportion to the quantity of the falling rains. If this were strictly and generally true, it will seem to follow from thence that the glass should stand highest when the air is fullest of clouds and vapours, because it is then most burdened, and lowest when the rains are quite over, because the air is then most lightened. But by experience the mercury is usually low in cloudy and rainy weather, because the air is then lighter, and may often be observed to rise for several hours before the rains are over. I do not say Dr. Wallis' opinion is (*Page* 48) false, but only that is not absolutely true in all cases. When the regions above are calm, and at the same time crowded with clouds, discharging themselves in heavy and plentiful rains, the quantity falling will, it is reasonable to imagine, in some degree lessen the pressure of the atmosphere, because by the interposure of large and bulky clouds the free influx of the circumambient air is in some measure, and for some time, intercepted and excluded; but when the communication is open and the clouds broken or dissipated, the free and regular accession of new air will add more to the pressure upon the stagnant mercury than the falling rains detract from it. The highest (*Page* 49) rise of the barometer must be ascribed to a concurrence of circumstances, including the suspension of the vapours in the air, as also (as suggested by Boyle) to the (*Page* 71) escape of subterranean chinks during droughts. To what height the vapours ascend does in a great measure depend upon the degree of heat wherewith they are actuated, and upon the lightness of the vapours themselves, upon the density of the air wherein they are buoyed up, and even sometimes upon the strength and force of the winds wherewith they are impelled. Some of them are so far attenuated and rise to so great a height as not to be distinctly visible, of which kind, in Sir Isaac Newton's opinion, are those that form by refraction the blue colour of the sky. Other vapours of a grosser kind being compacted into clouds, and keeping for some time a fixed station in (*Page* 72) the regions above, have (as Boyle tells us) been ordinarily measured to the height of one-fourth or one-third of a mile, and some to half-a-mile; but that very few, and those of the whitest and in appearance the loftiest clouds, were upon trial found to be above three-fourths of a mile in height. In France or Italy clouds have been observed at 2000, 3000, or even 4000 geometrical paces high, but none have exceeded 5000 paces, or 5 miles in height. The same heights, or perhaps greater, might be sometimes discovered here if observations were made. Thus the day after the storm of 1703, a cloud passed over Oxford which good mathematicians considered was at least five miles (*Page* 73) in height, judging by sight only. The cloud might have got such an impetus from the storm as to be carried in a straight line so as to rise higher above the earth. Hence, it may be, the cause of rain coming on with a fall of wind is that such clouds as have thus been carried on by an horizontal impulse, then fall, owing to their superior (*Page* 74) gravity, and pass into rain. The cloud noticed by Ricciolus as being higher than the projected shadow of the earth, was probably a luminous cloud [=aurora]. Dr. Halley calculates that the Mediterranean may yield 5280 millions of tons of vapour in a day, and that with a drying wind for two or three rainless days the quantity supplied and kept in the air at once may be over 30,000 millions of tons of water. And by this means it is possible for some parts of the atmosphere to be sometimes even

saturated or overcharged with vapours, which, as they afterwards happen either to be driven and dispersed or collected and accumulated by the winds, will accordingly pro- (*Page* 78) duce moderate or plentiful supplies of rain upon some parts of the continent, (*Page* 82) or excessive quantities in others. Sometimes we may discover two distinct squadrons of clouds floating at different heights, in streams of air directly contrary; sometimes the clouds meet and mix and increase all of a sudden in bulk and quantity. (*Page* 83) The common hygroscopes depend altogether upon the moisture or dryness of the air near the surface of the earth. If we suppose, as it sometimes happens, the (*Page* 84) lower region of the air to be moist when all above has a tendency to be fair and dry, or the lower region to be dry when all above has a tendency to wet weather, it is certain that no conjectures taken from part of the atmosphere can be so well grounded as what is derived from the more general and prevailing quality of the whole [viz. (*Page* 101) that shown by the barometer]. If in changeable or fair weather the surface of the mercury appears to be concave the weather will in a few hours become cloudy, and sometimes rainy or windy.

1786.

Franklin, Benjamin. (*B.* 1786, 2.)

(*Page* 51.) Hygrometers have been defective owing to their being themselves colder (*Page* 52) or warmer than the air during sudden changes. Their sensitiveness is a disadvantage, as means can only be obtained by making constant observations day and night for long periods. A substance slow to acquire and part with moisture would be (*Page* 56) the best to make an hygrometer of. Such would be a piece of mahogany fitted with movable hands and a marked scale. If these instruments were kept in the same place while making, and were graduated together, they would serve as comparable hygrometers, which would give the mean dryness of different countries.

Oliver, A. (*B.* 1786, 3.)

(*Page* 88) Paper read January, 1774. Whatever the immediate cause of evaporation may be, it is certain that the superficial moisture of all bodies is perpetually exhaling in vapour, which ascends into the higher regions of the atmosphere where they gather (*Page* 89) together into clouds and at length recondense as dew, mist, or rain. These vapours are either detached in streams from the humid ground by the influence of the sun, or thrown off by the perspiration of those infinite multitudes of animals and plants which cover the face of the earth, or supplied by evaporation from the ocean or other large collections of water. Considering the vast extent of the ocean and the comparatively small degree of moisture of which the dry land is susceptible, we may conclude that a very small proportion of the clouds which are formed in the atmosphere are exhaled from the latter, and that the ocean is the grand source from whence they principally (*Page* 90) derive their origin. Our natural senses convince us that sea air is always replete with moist vapours. These vapours are at first generally invisible, but when the weather is cold they are always visible, and appear like a steam arising from boiling water. (This is always the appearance in a clear still morning when Fahr. marks 0 or (*Page* 100) lower.) If evaporation be performed independent of electricity should we (*Page* 108) not be enveloped in everlasting fogs? The water raised from the sea beneath waterspouts is forced upwards in the finest globules by the intruding air into (*Page* 109) the warm electrical air expelled from below, where it becomes converted into vapour. These vapours will be greedily attacked by the craving particles of air, now deficient of electrical matter and form a dense cloud, in like manner as thunder clouds are formed over the land. This cloud will then be ready to discharge rain. (Note. The water raised up by waterspouts is salt, but descends fresh, so that it must have undergone a natural distillation.)

Williams, Rev. Samuel. (*B.* 1786, 4.)

[His experiments on evaporation were made at Bradford in New England, but have a general bearing.]

(*Page* 118.) The experiments were made in 1771. I filled the vessel at the beginning of each month. I observed that in the beginning of the month, when the tube was nearly filled, it exhausted much faster than towards the latter end, when 1 or 2 inches of water were evaporated; and that the quantity of evaporation measured this way came out less than the quantity of rain that fell in the course of the year. In 1772 I examined the matter more carefully, and made the following experiments—

Experiment 1. I procured two cylindrical vessels, 3 inches in diameter and 6 inches deep, as much alike as could be made. One I filled with water once a month, as I had done in 1771, the other with the same kind of water once a week, and placed them about 6 inches apart, in such a manner as to be exposed to wind and sun, but covered from the rain. The one filled once a week was exhausted about one-third more than the other. In January and February the difference was a little less; in March and April a little more. In May the evaporation from the former was 6·35 inches; from (*Page* 119) the other 4·1 inches. I was hence convinced that by neither of these methods could the quantity of water that really evaporates from the sea, etc., be correctly estimated. For in the one case, after about an inch has been exhausted the surface is too much sheltered from the wind, while in the other the water has all the advantage of the wind and is heated by the sun and atmosphere to a greater degree than the water in seas, etc., and the quantity of evaporation comes out too much.

Experiment 2. To measure the quantity more accurately I tried to ascertain what it really was from the surface of a river. I filled one of the vessels with river-water, and placed it as before. The second I floated on a board in the middle of the Merrimack River, defending it from rain and dew by a disk of glass placed 8 inches above the tube, the mouth of which was half an inch above the surface of the river. My efforts were baffled by wind and waves; but I succeeded in the week August 26 to September 2. During that time there was little wind, still water, no rain, and no disturbances. The tube was exhausted 1·15 inches. No water got in, as the surface of the board within 6 inches of the tube was dry every morning and evening. In the other tube the evaporation was 1·5 inches, which gives a difference of ·35 inch. All the latter evaporations should be diminished in this proportion.

Experiment 3. I next tried what the evaporation was from the surface of the earth. On September 14, two days after rain, I sank one of the vessels into the earth in a light soil, so as to take up all the earth contained in a space equal to the contents of the vessel. Having carefully weighed the vessel with the earth it contained, I fixed it in the ground in a plain open field, where it was exposed to wind and sun, but defended from rain and dew. At the end of seven days I took it up, and, weighing it again, found it had lost 783 grains troy. The diameter of the vessel being 3 inches, its surface, expressed in whole numbers, was 9 square inches; this gives 87 grains per square inch, or ·34 inch that passed off in evaporation, reckoning 254 grains to a cubic inch of (*Page* 121) water. In the other vessel the evaporation was 1 inch. The conclusion is that the evaporation from the earth is but little more than one-third of the evaporation from water.

Experiment 4. I next tried what the evaporation was from plants and trees. On August 20 I took up four different sorts of plants with as much of the earth adjoining them as wholly covered their roots. Each plant, with the earth about it, being 6 inches square, I put into a wooden box of the same size and form. The boxes were covered with thin lead to prevent evaporation from them, and had two apertures at the top, one for the stem of the plant and one for watering it, which was stopped when not in use. Having taken the weight of each, I placed them on the ground. I added known

quantities of water, the amount being that presumed to be thrown off by them. At the end of thirty days I re-weighed them. The results were as follows:

	Weight of Plant.	Water evaporated in 30 days.
Apple tree	23 grains	1271 grains.
Alder tree	30 "	2593 "
Spear mint	22 "	5186 "
Clover	43 "	1894 "

(*Page* 122) or 10,944 grains from the four, or about 43 cubic inches in 30 days. The evaporation from the vessel suspended in air during the same time was 4·25 inches in depth. The quantity, therefore, thrown off by the plants was more than what the evaporation would have been from a watery surface 10 inches square. The evaporation from vegetation would therefore be greater than from water over equal areas.

1793.

Dalton, J. (*B.* 1793, 1.)

(*Page* ix.) De Luc's idea of vapour seems not unlike mine. The hygrometer is an (*Page* 31) instrument meant to show the disposition of the air for attracting water, or for depositing the water it has in solution with it. To ascertain the exact quantity of water in a given quantity of air, and also the disposition of the air for imbibing or depositing, (*Page* 41) it is an object highly important to meteorology. The supposition of the clouds rising or falling with the barometer or as the density of the air increases or diminishes is not countenanced by Crosthwaite's observations on the clouds of Skiddaw. These observations also show that in very heavy and continued rains the clouds are mostly below the summit of the mountain (1050 yards); but it frequently (*Page* 98) rains when they are entirely above it. Prof. Musschenbroek ascribes the (*Page* 99) barometric variations to five causes, the fifth being that the air is loaded with (*Page* 100) or cleared of vapours and exhalations. As to the fifth cause it must be allowed that water when changed into vapour constitutes a part of the atmosphere for a time, and weighs with it accordingly; also that when the vapour is precipitated in form of rain the atmosphere loses the weight of it; but it would be hasty to conclude hence that where evaporation is going forward the barometer must rise, and where rain is falling it must fall also; because air loaded with vapour is found to be specifically (*Page* 101) lighter than without it. Evaporation, therefore, increases the bulk and weight of the atmosphere at large, though it will not increase the weight over any particular country if it displaces an equal bulk of air specifically heavier than the others; and in like manner rain at any place may not diminish the weight of the air there, because the place of the vapour may be occupied by a portion of air specifically heavier. It should seem, therefore, that when the air over any country is cleared of vapours, etc., the barometer ought to be higher than usual, and not lower. Clouds are (*Page* 103) never observed to be above four or five miles high. The barometric fluctuations are due mainly to changes in the density of the lower stratum of the air. (*Page* 104.) The more vapour air has in it the less is its specific gravity. Saussure found by experiment that a cubic foot of air at a certain temperature will imbibe 12 grains of water, and every grain of water dissolved in air becomes an elastic fluid capable of supporting $\frac{1}{24}$ in. of mercury, while its density to that of air is as 3 to 4. Priestley finds that gases of different specific qualities diffuse equally into each other. Sir B. Thomson found that moist air conducted heat better than dry air. A cubic foot of dry air mixed with a cubic foot of moist air would form 2 cubic feet, and be of equal elasticity with the simples. Hence, then, a fluctuation of the density of the air may happen thus; if a current of warm and vapourised air flow into a body of cold and dry air it will displace a part of the cold air and diffuse itself among the rest, by which means the weight of the stratum will be diminished, whilst its bulk

and spring remain the same; and *vice versâ*, if dry air flow into vapourised air. The (*Page* 106) first fact [that the barometer varies little at the tropics] may be accounted for thus;—the warmer any air is, the more water it will imbibe in similar circumstances; hence the air over the torrid zone being the hottest will contain the most vapour; and the air about the poles being the coldest will contain the least. (Note. The terms moist air and vapourised air denote air containing a great quantity of vapour irrespective of its humidity.) Moreover as the heat within the torrid zone (*Page* 107) fluctuates little, the variation of the barometer will be little. As the air at all times will endeavour to maintain a proportion of vapour suitable to its temperature, it follows that the air in general in the higher latitudes will then be both cold and dry, and in the lower latitudes both warm and moist, relatively speaking. The consequence is obvious, that, as a current from one or the other hand prevails, the barometer will rise or fall accordingly, and the rise or fall will be greater as the place is situate near to the extremes of temperature, because the air will in that case suffer the least change in its passage. In summer the heat all over the northern hemisphere is brought almost to an equality at the different parallels; the whole mass of air is heated, swelled, and replenished with vapour; the air over the northern regions is almost brought into the same state as within the tropics, and the barometer, therefore, has almost as little (*Page* 108) variation in that season here as there. As, independent of winds, heat and moisture will always be diffusing themselves in every direction where there is a deficiency of either, it seems impossible that the variations of the barometer should be local, though the amount of each fluctuation will not be the same at places considerably distant. The greater nearness of the mean height of the barometer to the higher extreme in winter than in summer may be thus explained. Moist air conducts heat better than dry air, and when the lowest extreme of the barometer happens, the air is moist, high winds generally prevail, and the atmosphere is much ruffled by clouds and storms; all these circumstances tend to diffuse the heat and to diminish the rate of decrease of temperature with height. (*Page* 110.) The mean weight of the column of air is thus lessened. The reason why (*Page* 112) the low extreme at Kendal, in Jan. 1789, followed the high extreme, is as follows. The extreme and long-continued cold preceding must have reduced the gross part of the atmosphere unusually low, and condensed an extraordinary quantity of dry air into the lower regions; this air was succeeded by a warm and vapoury current coming from the torrid zone before the higher regions, the mutations of which in temperature and density are slow, had time to acquire the heat, quantity of matter, and elevation consequent to such a change below; these two circumstances meeting, namely, a low atmosphere, and the greater part of it constituted of light vapoury air, occasioned the pressure upon the earth's surface to be so much reduced. Hence, then, it should seem we ought never to expect an extraordinary fall of the barometer unless when an extra- (*Page* 114) ordinary rise has preceded, or, at least, a long and severe frost. It does not appear that cold alone has a tendency to increase the mean weight over any place, if so, it would be higher in winter than in summer contrary to experience; if, therefore, the mean state of the barometer be lower in the torrid zone than in the frigid zones, it (*Page* 119) is most probably effected by the vapoury air. The evaporation from the surfaces of living vegetables is much greater than from the same space of land uncovered with vegetables. Evaporation and condensation of vapour are made subservient to the more equal diffusion of heat over the different climates and places; evaporation being great in the torrid zone, a vast portion of heat is absorbed and rendered insensible, till, being carried northward or southward, the vapour is condensed and gives out its heat again, which, being diffused in the atmosphere, augments its temperature very (*Page* 132) considerably. Evaporation is promoted by heat, dry air, and a decreased weight or pressure of the atmosphere upon the evaporating surface. The first and (*Page* 157) second are known to have that effect, the last is proved to have such an effect by the air pump. Evaporation from land in general must be less than the rain

that falls upon land, otherwise there could be no rivers. From a series of experiments made in 1793, I found the mean daily quantity evaporated from a vessel of water in a situation pretty well exposed to wind and sun for thirteen days of March to be ·033 in. depth, the greatest ·064 in.; for twenty-one days of April the mean daily quantity was ·055 in., the greatest ·1115 in.; for twenty-six days of May the mean was ·0755 in., the greatest ·1346 in.; for fourteen days of June the mean was ·063 in., the greatest ·098 in.; for eight days of July the mean was ·122 in., the greatest ·195 in. I never found the evaporation from water any summer much to exceed ·2 in. in 24 hours in the hottest weather. From these experiments and other considerations it seems probable that the evaporation both from land and water in the temperate and frigid zones is not (*Page* 142) equal to the rain that falls there even in summer. When a precipitation of vapour takes place, a multitude of exceedingly small drops form a cloud, mist, or fog; these drops, though 800 times denser than the air, first descend very slowly owing to the resistance of the air, which produces a greater effect as the drops are smaller, as the resistances are as the square of the diameters. From this it appears that clouds consist- (*Page* 143) ing of very small drops may descend very slowly, which is agreeable to observation; if the drops in falling enter a stratum of air capable of imbibing vapour they may be re-dissolved, and the clouds not descend at all; and if the air's capacity for vapour increase they may be all imbibed and the cloud entirely vanish. On the other hand, if the precipitation goes forward, and the air below have its full quantity of vapour, the small drops meeting one another will coalesce and form large ones, and descend in the form of rain to the earth's surface. (Note. This account of the nature of clouds and of the mode of their rising and falling was suggested by a friend.) From the important observations on the height of the clouds [by Crosthwaite], we learn that they are seldomer above the summit of Skiddaw in November, December, January, and February than in the other months; this clearly indicates the effect of cold in restraining the ascent of vapour. Were the measurement extended above the summit of the mountains, it is probable from the apparent law of the table that there could not be many observations (*Page* 144) above 1300 yards in winter, nor above 2000 yards in summer. This, it must be observed, relates only to the height of the under-surface of the gross clouds. The small white streaks of condensed vapour which appear on the face of the sky in serene weather I have, by several careful observations, found to be from three to five miles above earth's surface. When vapour is condensed into small drops upon the surface of bodies on the ground it is called dew; it differs from rain in being condensed on or near the solid bodies receiving it, whereas rain is condensed in mid-air. At first sight it will seem inconsistent that condensation of vapour should occur in the air resting on the earth's surface, since it is generally supposed to be warmer than the air above; but it is a fact that after sunset and during the night in serene weather, the air is coldest at (*Page* 145) the earth's surface. And accordingly we find that dew and hoarfrost are more copious in valleys than in elevated situations. That dew depends upon this circumstance can hardly be doubted, because, when clouds or winds prevent it, there is (*Page* 151) little or no dew formed. When the barometer is very high, the air is either very dry or cold, or both; when very low it is very moist or warm, or both. (*Page* 196) Very dark and dense clouds pass over without rain when the barometer is high; whereas, when the barometer is low, it sometimes rains almost without any (*Page* 202) appearance of clouds. The condensation of vapour exposed to the common air does not in any manner depend upon the pressure of the air. The temperature of the air bears a relation to the condensation of vapour. Though the pressure of the air does not promote condensation, yet when the pressure is removed evaporation is promoted.

Wells, W. C. (*B.* 1818, 1.)

(*Page* 122.) The second edition of 'An Essay on Dew,' published in 1815, differs from the first chiefly in the form of several expressions, such as "repletion with moisture," instead of "saturation with moisture," as my theory is inconsistent with the idea of air being capable of dissolving water. In 1788, Patrick Wilson suggested that (*Page* 123) hoarfrost was attended with the production of cold; and in the same year Six mentioned, in a paper communicated to the Royal Society, that on clear and dewy nights the thermometer on the ground in a meadow was lower than one suspended six feet above it. Six attributed the cold partly to the low temperature of the air through (*Page* 124) which the dew had fallen, and partly to the evaporation of moisture from the ground. An experiment, in the autumn of 1811, induced me to investigate the subject. After giving some attention to it, I began to suspect that Wilson, Six, and myself were in error in ascribing the cold to the formation of dew, and arrived at the (*Page* 127) conclusions given in the present essay. Aristotle remarked that dew only appears on calm and serene nights. Musschenbroek says that dew forms in Holland while the surface is covered with a low mist; but as he mentions at the same time that it is deposited on all bodies indiscriminately, the moisture of which he speaks cannot properly be called dew. Other writers have also regarded clearness of the air as not being requisite for the production of dew, misled, probably, by observing on misty (*Page* 128) mornings copious dews which had been produced during preceding clear nights. I never knew dew to be abundant except in clear weather. In regard to the necessity of the air being still, Prieur is the only author who rejects it, and he affirms that a fresh wind is requisite for the production of dew. The remark of Aristotle, however, is not to be received in its strictest sense, as I have frequently found a small quantity of dew on grass, both on windy nights if the sky was clear, or nearly so, and on cloudy nights, if there was no wind. If, indeed, the clouds were high and the weather calm, I have sometimes seen on grass, though the sky was entirely hidden, no very inconsiderable quantity of dew. Again, according to my observation, entire stillness of atmosphere is so far from being necessary for the formation of this fluid that its quantity has seemed to me to be increased by a very gentle motion in the air. Dew, however, has never been seen by me on nights both cloudy and windy. If in the (*Page* 129) course of the night the weather, from being calm and serene, should become windy and cloudy, not only will dew cease to form, but that which has formed will either disappear or diminish considerably. In calm weather, if the sky be partially covered with clouds, more dew will appear than if it were entirely covered, but less than if it were entirely cleared. Dew, probably, begins in this country [= England] to appear upon grass, in places shaded from the sun during clear and calm weather, soon after the heat of the atmosphere has declined. I have had few opportunities for making such observations, but I have frequently felt grass moist, in dry weather, several hours before sunset. On the other hand, I have scarcely ever known dew to be present in such quantity upon grass as to exhibit visible drops before the sun was very near the horizon, or to be very copious till some time after sunset. It also continues to form in shaded places after sunrise; but the interval between sunrise and its ceasing to form is, according to my observation, which upon this point has not been extensive, considerably shorter than that between its first appearance in the afternoon and sunset. Contrary, (*Page* 130) however, to what happens at sunset, if the weather be favourable, more dew forms a little before, and in shaded places a little after, sunrise than at any other time. Musschenbroek, therefore, errs greatly when he says that dew does not form after the sun has risen. The preceding observations on the early appearance of dew in the afternoon, are to be restricted to what happens to grass or other substances highly attractive of dew placed on the ground; for it occurs much later on similar substances

which are elevated a few feet above the ground, though upon these it continues to form as long after the rising of the sun as upon the others, if they be equally sheltered from the rays of that body. The formation of dew, after it has once commenced, continues during the whole night if the weather remains still and serene. Prieur, indeed, asserts that dew forms only in the evening, and that any which occurs in the former season always disappears in the course of the night. I can affirm, however, from long experience, that grass, after having been dewed in the evening, is never found dry till after sunrise, unless the weather has in the meantime changed. Upon one serene and still night I placed fresh parcels of wool upon grass every hour, and by weighing each (*Page* 131) of them after exposure for an hour found that they had all attracted dew. During nights that are equally clear and calm dew often appears in very unequal quantities, even after allowance has been made for any difference in their lengths. One great source of these differences is very obvious. For it being obvious that the more replete the atmosphere is with moisture the more copious will the precipitation be when the causes forming dew are in operation, and that all the circumstances which tend to (*Page* 132) increase the quantity of moisture must likewise tend to increase the quantity of dew. Thus dew, in equally calm and clear nights, is more abundant shortly after rain than during a long tract of dry weather. It is more abundant also throughout Europe, with perhaps a few exceptions, and in some parts of Asia and Africa, during southerly and westerly winds, than during those which blow from the north and east. Aristotle says that Pontus is the only country in which dew is more copious during a northerly than during a southerly wind. But a similar fact occurs in Egypt. Both cases, however, though contrary to the letter, are consonant with the spirit of the rule; since the north wind in the one country proceeds from the Euxine Sea, and in the other from the Mediterranean. Another circumstance of the same kind with the blowing of the wind from the south and west, as showing that the air contains much moisture, is the lessening of the weight of the atmosphere. My experience, indeed, on this point has not been great, as the falling of the barometer is very commonly attended with (*Page* 133) wind or clouds, both unfavourable to the production of dew; but still the greatest dews I have ever witnessed occurred while the barometer was sinking. A corresponding observation was made by De Luc, who says that rain may be foretold when dew is uncommonly abundant in relation to the season and climate. To the greater or less quantity of moisture in the atmosphere, at the time of the action of the immediate cause of dew, are to be referred several facts respecting its copiousness, the explanation of which is, perhaps, not quite so apparent as in the preceding examples. In the first place, dew is commonly more plentiful in spring and autumn than in summer; the reason is, that a greater difference is generally found between the temperatures of the day and night in the former seasons of the year than in the latter. In spring, this circumstance is often prevented from having a considerable effect by the opposite influence of northerly and easterly winds; but during still and serene nights in autumn dew is almost always highly abundant. In the second place, dew is always very copious in those clear and calm nights which are followed by misty or foggy (*Page* 134) mornings, the turbidness of the air in the morning showing that it must have contained during the preceding night a considerable quantity of moisture. Thirdly, I have observed dew to be unusually plentiful on clear mornings which had succeeded a cloudy night; for the air, having in the course of the night lost little or no moisture, was in the morning more charged with watery vapour than it would have been if the night had also been clear. Fourthly, heat of the atmosphere, if other circumstances are favourable—which, according to my experience, they seldom are in this country—occasions a great formation of dew. For as the power of the air to retain watery vapour in a pellucid state increases considerably faster while its temperature is rising in proportion to the heat acquired, a decrease of heat, in any small given quantity during the night, must bring it, if the temperature be high, much nearer to the point of

repletion, before it be acted upon by the immediate cause of dew, than if the temperature be low. We read, accordingly, in the writings of those who have travelled into hot climates of a copiousness of dew frequently observed by them there, which very much exceeds what occurs at any time in this country. But even here, dew, though for the most part scanty in our hottest season, is sometimes very abundant during it; an (*Page* 135) example of which occurred to me on the night common to the 29th and 30th of July, 1813; for on that night, notwithstanding its shortness, more dew appeared than has ever been observed by me on any other. In the last place, I always found when the clearness and stillness of the air were the same, that more dew was formed between midnight and sunrise than between sunset and midnight, though the positive quantity of moisture in the air must have been less in the former than in the latter time, in consequence of a previous precipitation of part of it. The reason, no doubt, is the cold of the atmosphere being greater in the latter than in the prior part of the night. But there are many circumstances influencing the quantity of dew, though much more open to accurate observation, are yet much less easy to be understood. In my first attempts to compare the quantity of dew formed during different times or in different situations, I attended only to the appearance which it made on bodies having smooth surfaces. But quickly seeing this method to be very imperfect, I next employed wool (*Page* 136) to collect dew from the atmosphere, and found it well adapted for my purpose, as it readily admits amongst its fibres the moisture which forms on its outer parts, and retains what it receives so firmly that I never but once had occasion to suspect that it suffered any portion of what it had thus acquired to pass entirely through it. The wool which I used was white, moderately fine, and already imbued with a little moisture from having been long exposed to the air of a room in which no fire was kept. I divided it into parcels of 10 grains each, and immediately before exposure pulled the fibres of every parcel somewhat asunder, so as to give it the form of a flattened sphere, the greatest diameter of which was about 2 inches. The parcels, probably, differed a little in size, but not enough so to affect the accuracy of the experiments, which were made in a garden in Surrey, about three miles from Blackfriars (*Page* 137) Bridge, but not more than $1\frac{1}{4}$ mile from a densely-built part of the suburbs on the south side of the Thames. The garden was level, and nearly half an acre in extent. At one end was a dwelling-house, at the other a range of low buildings; on one side a row of high trees, on the other a low fence dividing it from another garden. Towards one end there was a grass plat, in length 62 feet, and nearly 16 feet broad, the herbage of which was kept short by frequent mowing. The rest of the garden was employed for the production of culinary vegetables. All of these circumstances, however trifling they may appear, had an influence on my experiments, and most of them, as will hereafter be seen, must have rendered the results less remarkable than they would have been if they had occurred on a wide open plain considerably distant from a large city. I now proceed to relate the influence which several differences in the situation, mechanical state, and real nature of bodies, have upon the production of dew. One general fact (*Page* 138) relative to situation is, that whatever diminishes the view of the sky, as seen from the exposed body, occasions the quantity of dew which is formed upon it to be less than would have occurred if the exposure to the sky had been complete. I placed, on several clear and still nights, 10 grains of wool upon the middle of a painted board $4\frac{1}{2}$ feet long, 2 feet wide, and 1 inch thick, elevated 4 feet above the grass-plat by means of four slender props of equal height, and at the same time attached loosely 10 grains of wool to the middle part of its under side. The two parcels were consequently only an inch asunder, and were equally exposed to the action of the air. Upon one night, however, I found that the upper parcel had gained 14 grains in weight, but the lower only 4. On a second night, the quantities of moisture acquired by like parcels of wool in the same situations as in the first experiment were 19 grains and 6 grains; on a third, 11 and 2; on a fourth, 20 and 4; the smaller quantity being

always gained by the wool attached to the lower side of the board. I bent a sheet of pasteboard into the shape of a house-roof, making the angle of flexure 90°, and leaving both ends open. This was placed one evening, with its ridge uppermost, upon the (*Page* 139) same grass-plat, in the direction of the wind, as well as this could be ascertained. I then laid 10 grains of wool on the middle of that part of the grass which was sheltered by the roof, and the same quantity on another part of the grass-plat fully exposed to the sky. In the morning, the sheltered wool was found to have increased in weight only 2 grains, but that which had been exposed to the sky 16 grains. In these experiments the view of the sky was almost entirely cut off from the situations in which little dew was formed. In others, where it was less so, the quantity gained was greater. Thus, 10 grains of wool, placed upon the spot of the grass-plat which was directly under the middle of the raised board, and which enjoyed, therefore, a considerable oblique view of the sky, acquired during one night 7, during a second 9, and during a third 12 grains of moisture; while the quantities gained during the same time by equal parcels of wool laid upon another part of the grass-plat which was entirely exposed to the heavens, were 10, 16, and 20 grains. As no moisture, falling like rain from the atmosphere could, in a calm night, have reached the wool in any of the situations where little dew was formed, it may be thought that the (*Page* 146) substances under which the wool was placed prevented, mechanically, the access of that fluid. But on this supposition it cannot be explained why some dew was always found in the most sheltered places, and why a considerable quantity occurred upon the grass under the middle of the raised board. A still stronger proof of the want of justness in this supposition is afforded by the following experiment. I placed upright on a grass-plat a hollow cylinder of baked clay, the height of which was 2½ feet and diameter 1 foot. On the grass surrounded by the cylinder were laid 10 grains of wool, which in this situation, as there was not the least wind, would have received as much rain as a like quantity of wool fully exposed to the sky. But the quantity of moisture obtained by the wool surrounded by the cylinder was only a little more than 2 grains, while that acquired by 10 grains of fully exposed wool was 16. This occurred on the night during which the wool under the bent pasteboard gained only 2 grains of moisture. Dew will, however, in consequence of other varieties of situation, form in very different quantities upon substances of the same kind, although these should be similarly exposed to the sky. In the first place, it is requisite for the (*Page* 141) most abundant formation of dew that the substance attracting it should rest on a stable horizontal body of some extent. Thus, upon one night, 10 grains of wool laid upon the raised board increased 20 grains in weight; an equal quantity suspended in the open air 5½ feet above the ground, increased only 11 grains, notwithstanding that it presented a greater surface to the air than the other parcel. On another night, 10 grains of wool gained on the raised board 19 grains, but the same quantity suspended in the air on a level with the board only 13; and on a third, 10 grains of wool acquired on the same board 2½ grains of weight during the time in which other 10 grains hung in the air at the same height acquired only half a grain. In the second place, the quantities of dew attracted by equal masses of wool, similarly exposed to the sky and resting on equally stable and extended bodies, oftentimes vary considerably in consequence of some difference in the other circumstances of these bodies. Ten grains of wool, for instance, having been placed upon the grass-plat on a dewy evening, 10 grains upon a gravel walk which bounded the grass-plat, and 10 grains upon a bed of bare garden mould immediately adjoining the gravel walk, in the (*Page* 142) morning the wool on the grass was found to have increased 16 grains in weight, but that on the gravel walk only 9, and that on the garden mould only 8. On another night, during the time that 10 grains of wool laid upon grass acquired 2½ grains of moisture, the same quantity gained only half a grain upon the bed of garden mould; and a like quantity placed upon the gravel walk received no accession of weight what-

ever. Two objections will probably be made against the accuracy of these experiments with wool. One is, that wool placed on grass may, by a kind of capillary attraction, receive dew previously formed on the grass in addition to its own. To this I answer, that wool in a china saucer, placed on the grass, acquired very nearly as much weight as an equal parcel immediately touching the grass. The second objection is that a part of the increased weight in the wool might arise from its imbibing moisture as a hygroscopic substance. I do not deny that some weight was given to the wool in this way; but it may safely be affirmed that this quantity must have been very small. For, on very cloudy nights, apparently the best fitted to increase the weight of hygroscopic substances, wool upon the raised board would in the course of many hours (*Page* 143) acquire little or no weight; and in London I have never found 10 grains of wool, exposed to the air on the outside of one of my chamber windows, to increase during a whole night more than half a grain in weight. When this weight was gained the weather was clear and still; if the weather was cloudy and windy the wool received either less or no weight. This window is so situated as to be in great measure deprived of the aspect of the sky. It being shown that wool, though highly attractive of dew, was prevented, by the mere vicinity of a gravel-walk, or a bed of garden mould, for only a small part of it actually touched those bodies, from acquiring nearly as much dew as an equal parcel laid upon grass, it may be readily inferred that little was formed upon themselves. In confirmation of this conclusion I shall mention that I never saw dew upon either of them. Another fact of the same kind is that, while returning to London from the scene of my experiments, about sunrise, I never observed, if the atmosphere was clear, the public road or any stone pavement on either side of it to be moistened with dew, though grass within a few feet of it, and painted doors and windows not far from it, were frequently very wet. If, indeed, there was a foggy morning after a clear and calm night, even the streets of London would sometimes be (*Page* 144) moist though they had been dry the day before, and no rain had in the meanwhile fallen. This entire, or almost entire, freedom of certain situations from dew depends, however, much more upon extraneous circumstances than upon the nature of the substances found there; for river sand, though of the same nature with gravel, when placed upon the raised board, or upon grass, attracted dew copiously. A third difference, from situation, in the quantity of dew collected by similar bodies, similarly exposed to the sky, depends upon their position with respect to the ground. Thus, a substance placed several feet above the ground, though in this situation later dewed than if it touched the earth, would, notwithstanding if it lay upon a stable body of some extent, such as the raised board lately mentioned, acquire more dew during a very still night than a similar substance lying on grass. A fourth difference of this kind occurred among bodies placed on different parts of the raised board. For one that was placed at the leeward end of it generally acquired more dew than a similar body at the windward extremity. Differences in the mechanical state of bodies, though all other circumstances be similar, has likewise an effect on the quantity of dew which they attract. Thus, more dew is formed upon fine shavings of wood than upon a thick (*Page* 145) piece of the same substance. It is chiefly for a similar reason, I believe, that fine raw silk, fine unwrought cotton and flax were found by me to attract somewhat more dew than the wool I employed, the fibres of which were thicker than those of the other substances just mentioned. Bright metals attract dew much less powerfully than other bodies. Musschenbroek was the first who distinctly remarked this peculiarity of metals, but Dufay, I believe, published it before him (1736), referring at the same time the discovery to the proper author. Both Musschenbroek and Dufay, however, made too large an inference from their experiments, for they asserted that dew never appears on the upper surface of bright metals, whereas the contrary has since been observed by many persons, and I have myself known dew to form on gold, silver, (*Page* 146) copper, platina, iron, steel, zinc and lead. Dew, however, when it does

form upon metals commonly sullies only the lustre of their surface; and, even when it is sufficiently abundant to gather into drops, these are always small and distinct. Two other facts of the same kind are; first, that the dew which has formed upon metal will often disappear, while other substances in their neighbourhood remain wet; and secondly, that a metal which has been purposely moistened will often become dry, though similarly exposed with bodies which are attracting dew. This inaptitude to attract dew in metals is communicated to bodies of a very different nature, which touch or are near to them. For I have found that wool laid upon a metal will acquire much less dew than an equal quantity laid upon grass in the immediate vicinity. A large metallic plate laid upon grass resists the formation of dew more powerfully than a very small one similarly situated. I conclude, from various collateral facts, that a considerable difference in the thickness of two pieces of metal, exposing equal surfaces to the sky, will be attended with a similar consequence wherever they be placed, though I have no observation which proves this directly. If, however, a large and a very small (*Page* 147) plate be suspended horizontally in the air at the same height, the small plate will resist the formation of dew more powerfully than the large. If a metal be closely attached to a substance of some thickness, which attracts dew powerfully, the attraction of the metal itself for dew, instead of being increased from this circumstance, becomes diminished, provided the metal covers the whole of the upper surface of the other body. If only a part of this body be covered the production of dew on the metal is forwarded by the conjunction, and this somewhat in proportion to the quantity of surface in the body left uncovered. The justness of the first of these observations is proved by the following experiment. I joined, in the form of a cross, two pieces of very light wood, each 4 inches long, one-third of an inch broad, and one line thick. To one side of the cross I fastened, by means of mucilage, a square piece of gilt paper, and then exposed the instrument to the sky, with its metallic side uppermost, on a dewy night, in a horizontal position, about 6 inches above the ground. A few hours after the unattached part of the metalled paper was found covered with drops of dew, while those parts which adhered to the cross were dry. A large metallic plate laid upon grass was (*Page* 148) dewed with more difficulty on its upper surface than a similar plate elevated a few inches above the grass by means of slender props which allowed the air to pass freely under the metal. But the case with respect to small pieces was the reverse; for I have often seen covered with dew the metallic sheath of a small thermometer lying upon grass, while the similar sheath of another thermometer suspended in the air remained dry. Removing a metal several times in the course of the night from one part of the grass-plat to another facilitated its being dewed. The same effect was produced on gilt and silvered paper by first exposing them to the sky for some time with the bare side uppermost, and then turning them. If a piece of glass, covered on one side with a metal, be placed upon the ground with this side downward, the upper surface will attract dew precisely as if no metal were attached to the lower surface. The upper surfaces of metals are most readily and most copiously dewed on those nights and on those parts of the night during which other substances are the most readily and the most copiously dewed. If a metallic plate has been laid upon glass before dew began to form anywhere, its lower side, notwithstanding, always became moist in the course of (*Page* 149) the night; and the same effect was almost always observed if the plate had been placed horizontally in the air, a few inches above the grass. While the undersides were thus moist the upper surfaces were very often dry. If, however, the plate was elevated several feet in the air, the condition of both sides was always the same, whether this was dry or moist. The remarks hitherto made on the relation of metal to dew, apply to the class generally; but it is now to be mentioned that they do not all resist the formation of that fluid with the same force. I saw, for example, platina one night distinctly dewed, while gold, silver, copper and tin, though similarly situated, were entirely dry; and I have also several times seen these four metals free

from dew, while iron, steel, zinc and lead were covered with it. I once supposed, in consequence of the difficulty with which metals are dewed, that they might in all circumstances resist, in a greater degree than other bodies, the condensation of watery vapour upon their surface; and I afterwards found that Le Roi (1751) asserts this to be the case. But having exposed at the same time to the steam of warm water (*Page* 150) pieces of glass and of metal I did not see that moisture formed in the least more readily upon the former than upon the latter. Saussure came to the same conclusion. Le Roi said that dew is never deposited by the air of cities. With the view of testing this, I frequently exposed at night 10 grains of wool upon a slight wooden frame, placed in such a manner between the two ridges of the top of my house, which is situated in one of the most crowded districts of London, as to be 3 feet distant from the nearest part of the roof. The event was that upon clear and calm nights dew was always acquired by the wool, though never in any considerable quantity; probably, however, more from the wooden frame being nearly surrounded by buildings much more elevated than itself, than from any particular condition of the air in cities. The formation of dew, in this situation, proceeded much less (*Page* 151) regularly than in the country. For upon one evening 10 grains of wool gained in it 3 grains of moisture in one hour and eighteen minutes, though I scarcely ever knew a greater quantity to be collected by a similar parcel of wool in the same place during a whole night. Dew may be obtained every fine evening upon grass in London. But as dew upon grass is said by Le Roi to proceed from the ground and not from the atmosphere, the argument derived from its appearance there in cities against this assertion is thus eluded by him. From the time of Aristotle (*Page* 152) hoarfrost has justly been considered as frozen dew. Dew is often spoken of as being cold by popular writers, as Cicero and Virgil. I have found the ground (*Page* 153) colder than the air some feet above it several degrees on dewy nights, some- (*Page* 154) times as much as 14°. I did not speak in the preceding section of another obscure state of the atmosphere, that occasioned by fog or mist, as the moisture deposited attaches to all bodies indiscriminately, on which account I was unable to determine whether or not dew forms during its continuance. But with respect to the connexion of this condition of the atmosphere with cold, I have to remark that I have several (*Page* 158) times on its appearance betwixt day-break and sunrise found the difference between thermometers on grass and in the air, which had been considerable during the night, to diminish considerably. I never, indeed, observed it to vanish. I have now, however, reason to doubt the justness of this conclusion; for on the evening of Jan. 1, 1814, I found during a dense fog, while the weather was very calm, a thermometer lying on grass thickly covered with hoarfrost 9° lower than another suspended in the air 4 feet above the former. On the following evening, when the air was equally calm, but the fog sufficiently attenuated to allow me to see that the sky was almost covered with clouds, the difference between two thermometers, similarly placed with the former, was only 1°. On comparing the observations of these two evenings, I conclude that on the first few or no clouds existed above the fog, and consequently that fogs, if there be no clouds above them, may in a very calm air admit of the appearance of a considerable degree of cold at night upon the surface of the earth in addition to that of the atmosphere.

He mentions several other observations shewing that the greater the number of degrees the ground was colder than the air above, the more abundant was the dew. Dew, according to Aristotle, is a species of rain formed in the lower atmosphere in consequence of its moisture being condensed by the cold of the night into minute drops. Gersten, who published his treatise on dew in 1733 [1732], proved these opinions to be erroneous: for he found that bodies a little elevated in the air often become moist with dew, while similar bodies lying on the ground remain dry, though necessarily from their position as liable to be wetted by whatever falls from the heavens as the former. Musschenbroek remarks that metals will be free from dew while other bodies attract it.

(*Page* 178) copiously. Dufay concluded from this that it might be an electrical phenomenon, since it leaves untouched the bodies which conduct electricity, while it appears upon those which transmit that influence. If dew were to collect on the latter only, its quantity would never be sufficiently great to admit its being distinctly seen; for the non-conductors, as soon as they became in the least moist, would be changed into conductors. Charcoal, too, it is now known, though the best solid conductor of electricity after the metals, attracts dew very powerfully, and in the last place dew frequently forms upon metals themselves. Other authors have considered dew electrical for other reasons; but there are several considerations which seem to me to prove that no such opinion can be just. 1. When dew is produced in a clear atmosphere the portion of air by which it is deposited must necessarily be unable at that point to retain in a state of pellucid vapour all the moisture which it had immediately before held in that form. But I know of no experiment which shows that air by becoming positively electrical, which is said to be its condition on the evenings during which dew is most abundant, is (*Page* 179) rendered less able than it had previously been to contain watery vapour in a state of transparency. 2. Bodies in similar circumstances, as far as electricity is concerned, acquire very different quantities of dew. 3. Dew forms in different parts of the night in quantities no way proportioned to the degrees of electricity found in the atmosphere at the same times. Thus it is commonly more copious in the morning than in the evening, notwithstanding that the air is observed to be in the latter season more highly electrical than in the former. 4. I have several nights held a glass bottle, upon which dew was forming, close to the top of a Bennett's electrometer which had been previously kept in a dry place, but I never saw the slips of gold-leaf move in consequence. It is very probable, however, that more refined experiments will show that electrical appearances attend the production of dew. But the facts that have been stated (*Page* 180) seem sufficient to establish that any such appearances which may be hereafter remarked during the formation of dew, must be considered as the effects and not as the cause of the conversion of the watery vapour of a clear atmosphere into a fluid. A remaining argument applies equally to all the theories which have hitherto been made public on the cause of dew. This is that none of them include the important fact that its production is attended with cold. Previous writers considered that the cold was caused by the dew [see under, 1793. Dalton, *pages* 144, 145]. I began to doubt its truth on finding that bodies would sometimes become colder than the air without becoming dewed, and that when dew was formed, if different times were compared its quantity and the degree of cold which appeared with it were very far from being always in the same proportion (*Page* 181) to each other. At last I was convinced that dew is the production of a preceding cold in the substances upon which it appears. Wishing to obtain more striking proofs I instituted experiments. I commenced these on the raised board as soon as the sun ceased to shine on it. The first day, Aug. 19, 1813, was a favourable one. There had been no rain for weeks, the wind was northerly, and the barometer was rising; all which indicated that the atmosphere contained little moisture. The air, too, was extremely still. The only appearance in the least unfavourable was that the sky was not entirely free from clouds; but these were few, of small extent, thin and high. At 6 h. 25 m., immediately after the sun had ceased to shine upon the spot where my experiments were to be carried on, though the time of its setting was still 47 minutes distant, I placed upon the raised board 10 grains of wool, and a small bag made of the skin of a swan's breast, with the down adhering, and stuffed with wool, the whole weighing 5 drachms. On each of these substances the naked bulb of a small but delicate thermometer was laid. A similar thermometer, with its bulb also naked, was suspended in the air over the grass-plat at the same height with the board. After an exposure of 20 minutes, the wool was 7° colder than the air, but the swan-down bag only 6°, no doubt in consequence of its greater quantity of matter. Neither, however, had gained the least

weight according to the scales, which would turn to the one-sixteenth of a grain. These observations were repeated several times during the hour, at none of which, except the last, was either the wool or swan-down found in the least heavier than when (*Page* 183) first placed on the board. At this last observation the wool, though 9½° colder than the air, was still without any increase in weight; but the swan-down which was 1° colder than the wool, had gained half a grain. I again examined the thermometer at 8h. 45m. The wool, which was still 9½° colder than the air, had gained somewhat less than half a grain, and the swan-down, which was now 11½° colder (*Page* 185) than the air, had gained 2 grains. I shall next apply the facts observed to the explanation of several atmospherical appearances. The variety in the quantities of dew which was found by me upon bodies of the same kind exposed to the air during the same time of the night, but in different situations, is now seen to have been occasioned by the diversity of temperature which existed among them. The cold connected with dew is not proportional to tho quantity of it. The same degree of cold (*Page* 186) may be attended with much, with little, or with no dew, according to the existing state of the atmosphere in regard to moisture. The formation of dew produces heat. I infer this partly because very little dew appeared upon the two nights of the greatest cold I have ever observed upon the surface of the earth relatively to the temperature af the air, both of them having occurred after a long tract of dry weather, and partly from the most dewy night I have ever seen having been attended during the greater part of it with no considerable degree of cold. On this night the difference between the temperature of grass and of air was at first 7½°, the dew being then not very abundant. But after the dew had become very abundant, the difference of these temperatures never exceeded 4°, and was frequently only 3°. The (*Page* 188) less difference commonly observed between the temperature of grass and of air in the morning, than what occurs in the evening is likewise to be in part attributed to a greater quantity of dew appearing in the former than in the latter season. In (*Page* 189) very calm nights a portion of air, which comes in contact with cold grass, will not, when the surface is level, immediately quit it, more especially as this air has become specifically heavier than the higher, from a diminution of its heat, but will proceed horizontally, and be applied successively to different parts of the same surface. The air, therefore, which makes this progress must at length have no moisture to be precipitated, unless the cold of the grass which it touches should increase. Hence, in great measure, is to be explained why in such nights as have been just mentioned, more dew was acquired by substances placed on the raised board than by others of the same kind on the grass, though it began to form much sooner in the latter than in the former situation, those on the raised board having received air which had deposited less of its moisture. A reason is now also afforded why a slight agitation of the atmosphere, when very pregnant with moisture, should increase the quantity of dew, since fresh parcels of air will hence be more frequently brought into contact with the cold surface of the earth than if the atmosphere were entirely calm. Dew can never be (*Page* 190) formed in temperate climates upon the the naked parts of a living and healthy human body during the night; since their heat is never less in this season, in such climates, than that of the atmosphere. I have, in fact, never perceived dew on any part of my own body at night. On the other hand, in very hot countries the uncovered parts of a human body may sometimes, from being considerably colder than the air, condense the watery vapour of the atmosphere, and hence be covered with a real dew, even in the daytime.

(*To be continued.*)

SCIENTIFIC UNION.

The rapid progress of science now going on is, in part, the result of the great increase in the number of workers. This is accompanied by a larger and larger host of scientific serials. The consequence is that the student finds an increasing difficulty in ascertaining what has been done, or is in process of being accomplished, not only in his own special line of study, but also, and more particularly, in such as do not immediately interest him. Every student finds, from time to time, that he has a desire for full information on subjects in these outlying sciences, for the purpose of throwing light upon his special studies. The state of literature is such that he is frequently daunted by the difficulties attending his research, or, if he perseveres, he finds a great deal of time unnecessarily wasted. The remedy for this is the focalisation of knowledge round a series of centres. The two main steps in the process are, first, collection, and, next, classification. It is, with this ulterior object in view, that all persons interested in meteorology are earnestly asked to forward their names and addresses, particulars as to the work they have done in meteorological and other sciences, their present lines of study, ways in which help is desired, and any other items that may occur to them. These details will be classified, and, when the opportunity offers, selections from them will be published. The Conductor will exercise careful discretion in the selection, as also in the use he may make of the more private details. The first list will be published in November, 1883; but correspondents are requested to send in answers soon, in order to allow of ample time for their classification, and for their utilisation in private correspondence in the interests of correspondents.

In order to prevent any misconception, it may be stated that the Conductor's object is solely to promote scientific union, and is no way intended to be of a charitable nature in any pecuniary sense. If there is a sufficient response to these requests, the same line of proceeding will hereafter be suggested, from time to time, for the students in other branches of science.

Newspapers and scientific journals of all countries, willing to help in this matter, are asked to make the above requests known to their readers.

Address, Conductor, "Scientific Roll" office, 7 Red Lion Court, Fleet Street, London, E.C.

THE SCIENTIFIC ENQUIRER.

Correspondence is invited on scientific subjects of all kinds. In all cases names and addresses should be given; but these will not be published if the writers prefer noms de plume. The Conductor will not be responsible for the opinions expressed by correspondents. All communications should be addressed to the Conductor of the "Scientific Roll," 7 Red Lion Court, Fleet Street, London, E.C.

Replies to questions should be numbered in accordance with the questions to which they refer. The contractions following the questions and answers indicate the class of notes to which they will ultimately be assigned, and the place where full references will be given to the details bearing upon them.

M. Mammalia; *R.* Reptilia; *L.* Lepidoptera; *O.* Orthoptera.

Mimetic Resemblances and Mimicry in Animals. (Tiger, Leopard, *Viverra*, Crocodiles, Moths, and *Mantis*.)

Some sketches, illustrative of a remarkable case of a caterpillar belonging to a species of moth the name of which we have not been able to ascertain, have been sent to us by S. E. Peal, of Aideo, in Asam. The caterpillar has a striking resemblance to a species of *Viverra* inhabiting the same district. We are also indebted to the same correspondent for the following note.

"The most general and interesting law, as far as I see, in the mimicry of inanimate things by animals, or insects, is the remaining quite still till the last possible moment. I often pin moths ere they move, and catch butterflies with my fingers. The range that this quality takes is also much wider than is usually supposed; not only is it for protection, as in 'protective resemblance' (as when a caterpillar exactly resembles the buds it feeds on and lives among); but also as a means of luring insects, as in the *Mantis* that resembles a blossom. Again, the tiger imitates the whistle of the large Sambur deer here (to call it) so closely that only a trained ear can tell the difference. The leopard also imitates the smaller deer. It is a common custom of all hunters to call deer by whistling with a leaf, and I have done it myself. Occasionally, as might be expected, a tiger, and not a deer, turns up at close quarters, when the astonishment is mutual. The crocodile's eye and nose floating on our muddy waters also exactly resembles the lumps of dirty foam so common here, and I have often, in my Rob Roy canoe, passed close to one and knew he would not move. There is a *Viverra* in these hills, so far unknown to me, but it catches hawks by hiding its body under a bare and very conspicuous branch of a tree, as in these hill-clearings, while it turns its tail over on top and keeps jerking it; any hawk within range at once takes it for a squirrel, and, acting accordingly, gets caught."

The statements respecting the *Viverra* depend upon the testimony of individuals belonging to the Naga tribe.

The following questions are suggested by the above:—

1. Are any other cases known of lepidopterous caterpillars resembling species of Mammalia? (L. 1.)

2. Would readers supply instances of caterpillars resembling species belonging to other classes of animals than the Mammalian? (L. 2.)

3. What mimetic resemblances are there between caterpillars and the various parts of plants, as twigs, buds, etc.? (L. 3.)

4. What instances are there of mimetic resemblances in *Mantis* and other genera of the same family to the leaves, stems, blossoms and other parts of plants? The names of the animals and plants should be given, and such particulars as regards habits, etc., as seems to afford some explanation of the phenomena. (O. 1.)

5. What instances are there of the *Carnivora* imitating the call of their prey for the purpose of luring them? (M. 1.)

6. What instances are there amongst the reptiles of mimetic resemblance to inanimate objects? (R. 1.)

7. What instances are there amongst the species of *Viverra* of cunning displayed for the purpose of inducing the near approach of prey? (M. 2.)

We shall be glad to have any other questions and notes on the subject.

ANNOUNCEMENTS.

Part III. of the "Scientific Roll" will be commenced, if life and health and support be granted to the Conductor, in 1883. In order that the bibliography may be as full as possible, authors and publishers are respectfully solicited to send copies of, or references to, all their publications dealing with the barometrical condition of the air.

As soon as 200 persons have expressed a wish to subscribe for any of the subjects mentioned below, the publication of that section of the "Scientific Roll" will be forthwith commenced. The subscription price will be 7*s.* 6*d.* and 10*s.* for each volume, according as the residence of the subscriber is at home or abroad. Each volume will comprise from 400 to 500 pages; and each volume will, in most cases, contain two or more parts, each of which may be subscribed for separately. The extent of these parts will depend upon the amount of matter in hand, so that the subscription price for each cannot be fixed at present, but will be settled when the publication of each part is commenced. The following is a list of the principal subjects:—

Atmosphere, Water, Ocean, Rivers, Lakes, Glaciers, Land, Elevation and Subsidence of Land and Sea Bottom, Denudation, Orography, Earthquakes, Volcanoes, Marshes, Minerals, Stratigraphy, Rocks, Plants generally and in classified groups; Animals generally; Protozoa, Actinozoa, Hydrozoa, Echinodermata, Crustacea, Scolecida, Annelida, Mollusca, Myriapoda, Arachnida, Rhynchota, Orthoptera, Diptera, Coleoptera, Lepidoptera, Neuroptera, Hymenoptera, Pisces, Amphibia, Reptilia, Aves, Mammalia, and Man.

Subscribers' names only are asked for now. The sending of these will not involve any pecuniary liability, but will simply be taken as implying that the senders take an interest in the work, and will probably undertake to subscribe when asked to do so.

AQUEOUS VAPOUR: NOTES.

1818.

Wells, W. C. *Concluded from page* 205 (*B.* 1818, 1).

(*Page* 190) Hygrometers formed of animal or vegetable substances, when exposed to a clear sky at night, will become colder than the atmosphere, and hence, by attracting dew, or, according to an observation by Saussure, by merely cooling the air contiguous to them, mark a degree of moisture beyond what the atmosphere actually contains. [See under 1786.—Franklin (*Page* 51).] This serves to explain an observation made by De Luc, that in serene and calm weather the humidity (*Page* 191) of the air, as determined by the hygrometer, increases about and after sunset with a greater rapidity than can be attributed to a diminution of the general (*Page* 202) heat of the atmosphere. Dew appears chiefly where it is most wanted, on herbage and low plants, avoiding in great measure rocks, bare earth, and considerable masses of water. (Note.—I have no direct observation for this assertion concerning considerable masses of water. But I hold it, notwithstanding, to be just; because as soon as the surface of the water is in the least cooled by radiation, the particles composing it must fall downwards from their increased gravity, and be replaced by others that are warmer. The whole mass, therefore, can never, in the course of a single night, be sufficiently cooled to condense into dew any great quantity of the watery vapour of the atmosphere. Besides, I have found that even a small mass of water sometimes acquires no weight from the reception of dew in the space of a whole night favourable (*Page* 203) to the formation of that fluid.) Its production, too, tends to prevent the injury that might arise from its own cause, since the precipitation of water upon the tender parts of plants must lessen the cold on them which occasions it. The appearance of dew is not confined to any one part of the night, but occurs during its whole course, from means the most simple and efficacious; for after one part of the air has deposited its moisture on the colder surface of the earth, it is removed in consequence of that agitation in the air which exists during its stillest states, and gives place to another having its quantity of water undiminished; and again, as the night proceeds, a portion of air, which had before deposited all the moisture which circumstances at that time permitted, is rendered fit, by the general increase of the cold of the atmosphere, to give out a fresh parcel when it comes anew into contact with the ground. (*Page* 210.) The water deposited upon the earth during a fog at night may sometimes be derived from two different sources, one of which is a precipitation of moisture from a considerable part of the atmosphere in consequence of its general cold; the other, a real formation of dew, from the condensation, by means of the superficial cold of the ground, of the moisture of that part of the air which comes in contact with it. In such a state of things all bodies will become moist, but those especially which most readily attract dew in clear weather. (Note.—The moisture observed at night by Musschenbroek in Holland, and called by him dew, appears to me to have been of this nature.) (*Page* 212) Wilson (1780) observed the prominent parts of various bodies to be crusted (*Page* 214) with hoar frost, while their more retired and massy parts were free from it. The more hurtful effects of cold in hollow places may be in part due to the air being retained there; and consequently, as less dew is deposited, less heat will be extricated during

(*Page* 215) its formation. Pictet ascribed the greater cold upon plains than upon neighbouring hills to the evaporation of moisture from the ground. To show that this is not so, it need only be mentioned that the appearance never occurs in any considerable (*Page* 216) degree except upon such nights as are attended with some dew, and that its great degrees are commonly attended with a copious formation of that fluid; since it cannot be thought that the same stratum of air will deposit moisture upon the ground from an insufficiency of heat at the very time it is receiving moisture from the ground in the state of pellucid vapour, as this supposes that it is not yet replete with water. (*Page* 226) Aristotle and Plutarch observed that dew is much less copious upon hills than upon plains. This may be explained thus. For allowing at first the surface of the ground to be in both positions equally colder than the air which is near to it, still, as the production of dew must be in proportion to the whole depression of the temperature (*Page* 227) of the air which furnishes it, below what its heat had been in the preceding day; and as one part of this depression, the general cooling of the atmosphere, is much more considerable on the plain than on the hill, moisture must necessarily be deposited more copiously in the former than in the latter place. If the greater agitation of the atmosphere, and the less quantity of moisture during clear weather in its higher region than in the lower, be added, it may readily be inferred that dew shall sometimes be altogether wanting upon a hill, though abundant on a plain at its foot, agreeably to what has been actually observed by Mr. Jefferson. The leaves of trees often remain dry throughout the night, while those of grass are covered with dew. As this is a similar fact to the smallness of dew on hills, I shall, in accounting for it, do little more than enumerate the circumstances on which it depends. The atmosphere is several degrees warmer near the upper parts of trees on dewy nights than close to the ground. The air in the higher situation is more agitated than that in the lower. The air at a little distance from the ground, from being nearer to one of its sources of moisture, will on a calm evening contain more of it than that which surrounds the leaves of elevated (*Page* 228) trees. Only the leaves of the very tops of trees are fully exposed to the sky. The declension of the leaves from a horizontal position will occasion the air which has been cooled by them to slide quickly away and be succeeded by warmer parcels. The length of the branches of the trees, the tenderness of their twigs, and the pliancy of the footstalks of their leaves, will cause in the leaves an almost perpetual motion, even in states of the air that may be denominated calm. I have hence frequently heard, during the stillness of night, a rustling noise in the trees which formed one of the boundaries of the ordinary place of my observations, while the air below seemed without motion. Nearly in the same manner is to be explained why shrubs and bushes also receive dew more readily than lofty trees. Bright metals exposed to a clear sky in a calm night will be less dewed on their upper surface than other solid bodies, since of all bodies they will in such a situation lose the smallest quantity of heat by radiation to the heavens, at the same time that they are capable of receiving by conduction at least as much heat as any others from the atmosphere, and more than any others from the warmer solid substances which they happen to touch. If the (*Page* 229) exposed pieces of metal be not very small, another reason will contribute somewhat to their being later and less dewed than other solid substances. For, in consequence of their greater conducting power, dew cannot form upon them unless their whole mass be sufficiently cooled to condense the watery vapour of the atmosphere; while the same fluid will appear on a bad conductor of heat, though the parts a very little beneath the surface are warmer than the air. (Note.—I hence think it probable that dew will sometimes form on the bulb of a thermometer before the mercury in it is cooled below the temperature of the air. It seems certain to me also that dew may appear upon substances which, from the thinness of the layer of matter their cold is confined to, will produce little or no sensible effect upon a thermometer that is applied to them.) From the same ready passage of heat from one part of a metal

plate to another, a metallic plate suspended horizontally in the air several feet above the ground, will be found dewed on its lower side if the upper surface has become so, while the lower surface of other bodies, more attractive of dew, but worse conductors of heat, are without dew in a similar situation. A metal placed at night in the air near to the ground is for the most part sufficiently cold to condense on its under side the vapour (*Page* 230) which arises from the warmer earth, while the upper surface may be dry from possessing the same or almost the same temperature as the atmosphere near to it. As the temperature of metals is never much below that of the neighbouring air, a slight diminution of their cold from radiation will often enable them to evaporate the dew which they had previously acquired, though other substances which had been more cooled by radiation are still attracting dew. For a like reason, a metal which has been purposely wetted will often become dry at night, while other substances are becoming moist. A substance, highly attractive of dew, will derive heat from it, and will therefore acquire less dew than an equal portion of the same substance laid upon grass. A large metallic plate will be less readily dewed while lying on grass than if it were placed in the air, though only a few inches above the grass, because in the former situation it receives freely, by means of its great conducting power, heat from the earth, whereas when placed in the air it powerfully resists, by another property possessed in a great degree by bright metals, the entrance of heat radiated towards it by the grass (*Page* 231) beneath. Besides, the grass under the metal now has less heat than when in contact with it, partly from having a small oblique aspect of the sky, and partly from receiving air which has been cooled by passing over other grass fully exposed to the heavens. When a piece of metal, having closely applied to its under surface a substance of some thickness which attracts dew powerfully, and therefore imbibes readily heat that is radiant to it, is exposed to the sky at night, the heat supplied by the attached substance, both from its own original store and from what it has acquired through the radiation of the ground to it during the exposure, will enable this piece to resist longer than a bare piece, the formation of dew, or even than another piece which has only a thin coat of matter considerably attractive of dew, attached to its under side. A very small metallic plate suspended in the air is less easily dewed than a large one similarly situated, as it receives, in proportion to its size, more heat from the atmosphere. On the other hand, a very small plate laid upon grass rendered cold by radiation will be sooner dewed than a larger one in the same situation, from presenting a greater (*Page* 232) proportional circumference to the surrounding grass, and, therefore, losing more quickly its heat by conduction. It will be also sooner dewed than another very small one suspended in the air, since the latter, like other small bodies similarly placed, must be continually acquiring more heat than the former. A piece of metal applied to different portions of cold grass in succession will sooner become cold itself than another piece which is suffered to remain constantly upon one portion of the same grass, and will in consequence be sooner dewed. If the bare side of a piece of metalled paper be exposed to a clear and calm sky at night it will become cold by radiation, and receive by conduction the heat of the inferior metallic surface; whence, if this surface be afterwards made the upper one, it will sooner acquire dew than a similar metallic surface which has been exposed to the sky during the whole of the experiment. When a metal covers in part only the upper surface of a piece of glass, the uncovered portion of the glass generally becomes cold by radiation on exposure to a serene sky in a still night, and then, by deriving [? drawing] to itself a part of the heat of the metal, occasions this body to be more readily dewed than if the whole of the exposed surface (*Page* 233) had been metallic. In this experiment the outer edge of the metallic surface, from being nearest to the colder glass, will be the first and most dewed, while the parts of the uncovered glass which are contiguous to the warmer metal will be the last and the least dewed, of their respective substances. A piece of glass covered on one side with a metal being placed on the grass with this side down, its upper surface

attracts dew as readily as if no metal were attached to it, since the metal in this situation has no power to lessen the radiation of heat from the upper surface of the glass. I conclude, from general principles, that if the same piece of glass, having its metallic side still undermost, were raised in the air a little above the grass, it would be more readily dewed on its upper surface than if it had been without a metallic coating on the lower, as this coating must resist the introduction of heat radiated by the warmer grass, and thus preserve nearly undiminished the cold acquired from radiation of heat to the sky by the bare upper surface. The preceding remarks apply to the whole class of metals; but the discoveries of Mr. Leslie, respecting the difference in the capacities of these bodies to radiate heat, furnish an explanation among themselves in regard to attraction (*Page* 234) for dew, which was noted in a former part of this essay; gold, silver, copper and tin are there said to resist the formation of dew more strongly than other substances of the same kind; but these substances, according to Leslie, radiate heat the most sparingly. On the other hand, lead, iron and steel, which, according to the same author, radiate heat more copiously than the former metals, were found by me to acquire dew more readily. I do not know the radiating force of platina; but as its conducting power is small, its radiation must be great; and I have, accordingly, observed it to be dewed, while the four first mentioned metals were dry. (Note.—All the (*Page* 235) observations on dew made by Prevost may be accounted for by the two following circumstances: that substances become colder, by radiation, than the air before they attract dew; and that bright metals, when exposed to a clear sky at night, become colder than the air much less readily than other bodies.) Thinking it probable that black bodies might radiate more heat to the sky at night than white, I placed upon grass, on five different evenings, equal parcels of black and white wool. On four of the succeeding mornings the black wool was found to have acquired a little more dew than the white; whence I inferred that it had, in consequence of its colour, radiated a little more heat. But I afterwards remarked that the white wool was somewhat (*Page* 236) coarser than the black, which circumstance alone was sufficient to occasion a difference in their quantities of moisture. Another night I laid on the raised board a piece of pasteboard covered with white paper, and close to this a second piece, similar to the former in every respect, except that it was covered with paper blackened with ink. At daylight I saw hoar-frost on both pieces, but the black seemed to have a greater quantity than the white. A doubt, however, afterwards arose upon the accuracy of this experiment likewise; for as the light was faint when I viewed the two surfaces, the quantity of hoar-frost, though equal on both, might have appeared greater on the black than on the white, from the contrast of its colour with that of the former surface. But trials of this kind, as Leslie has observed, never afford firm conclusions; since a black body must always differ from a white in one or more chemical properties, and this difference may cause a diversity with respect to radiant heat. I have (*Page* 237) regarded dew as altogether derived from watery vapour previously diffused through the atmosphere. The establishment of a contrary opinion will not affect my conclusions. Other writers, however, have regarded dew as being entirely the product of the vapour emitted during the night by the earth and plants upon it. According to this theory dew is said to rise. The first traces I have found of the opinion that dew rises from the earth at night, occurs in the 'History of the Academy of Sciences' [of Paris] for 1687. It is mentioned there briefly and obscurely. Gersten in 1733 [1732] advanced it as new, and considered himself to be the author of it. Musschenbroek embraced it, but soon admitted that dew sometimes falls. The only argument used (*Page* 238) by the French academicians is, that as much dew is observed under an inverted bell-glass as in any other situation. But admitting, for a moment, this to be true, they could not thus prove that the ground is the only source of that fluid. Gersten was led to think that dew rises from the earth by often finding grass and low shrubs moistened with it, while trees were dry. But his chief argument is derived from

the fact that a plate of metal laid upon bare earth, on a dewy night, will remain dry on its upper surface while it becomes moist on the lower. I have otherwise explained this. (Note.—I have observed, on a cloudy night, a piece of glass laid over an earthen pan containing water and placed upon the ground, to be wet on its lower side, while the upper was dry, the glass being, in this situation, sufficiently cold to condense the vapour of water heated by the earth, but not enough so to condense the watery vapour of the atmosphere.) Gersten, moreover, describes several appearances himself which refute his opinion. He maintains, for example, that the higher parts of shrubs are more dewed than the lower; that metallic plates placed horizontally in the air are as much dewed on their superior as on their inferior surfaces; and that convex and cylindrical bodies suspended in the air, the latter having a position parallel to the horizon, are dewed only on their upper parts. The principal reason given by Dufay for the rising of dew is, that it appears more early on bodies near to the earth (*Page* 241) than on those which are at a greater height. This also I have accounted for otherwise. Dew often occurs when the rising of vapour from the earth at night can have little or no operation. It appears from Hasselquist and Bruce that, in Egypt shortly before the rising of the Nile, and consequently when the ground there is in its driest state, dew becomes exceedingly plentiful, though little or none had appeared before, while the earth was somewhat less dry. The cause evidently is the moisture brought from the Mediterranean by the north wind which then prevails. Webster, speaking of hoar-frost, candidly says: "This frost appears when the surface of the earth is sealed with frost, and, of course, the vapour of which it is formed cannot, at the time, perspire from the earth." I have myself, at all seasons of the year, frequently observed wool upon the middle of the raised board, and therefore out of the way of vapour rising from the ground, to acquire more dew than wool laid upon the grass-plat. The bodies that condense the rising vapour must necessarily be colder than it; but, as they are likewise, according to the opinion under view, of the same temperature with the air surrounding them, this also should condense the rising vapour. Dew, therefore, should never appear in any considerable quantity without being accompanied with fog or mist. Now, I can assert that the formation of the most abundant dew is consistent (*Page* 242) with a pellucid state of the atmosphere. Still, it must be admitted that some of the moisture which forms, during clear and still weather, on bodies situated upon or near its surface, is in most cases to be attributed to this source; since, in my experiments, substances on the raised board became much later moist than others on the ground, though equally cold with them. The quantity from this cause, however, can never be great. For, in the first place, until the air be cooled by the substances attractive of dew with which it comes in contact, below its point of repletion with moisture, it will be always in a condition to take up that which has been deposited on the grass or other low bodies by warm vapour emitted from the earth; just as the moisture formed upon a mirror by our breath is, in temperate weather, almost immediately carried away by the surrounding air. Accordingly, I have sometimes, in serene and still weather, observed dew to appear sparingly upon grass, in the shade, several hours before sunset, when it would increase considerably at the time that the same fluid began to show itself on the raised board. In the second place, though bodies situated on the ground, after they have been made sufficiently cold by radiation to condense the vapour of the atmosphere, will be able to retain the moisture which they (*Page* 243) acquire by condensing the vapour of the earth; yet before this happens the rising vapour must have been greatly diminished by the surface of the ground having become much colder. These considerations, added to the fact that substances on the raised board attracted rather more dew throughout the night than similar substances lying on the grass, warrant me to conclude that, on nights favourable to the production of dew, only a very small part of what occurs is owing to vapour rising from the earth; though I am acquainted with no means of determining the proportion of this

part to the whole. On the other hand, however, in a cloudy night, all the dew that appears upon grass may sometimes be attributed to a condensation of the earth's vapour, since I have several times, in such nights, remarked the raised board to be dry while the grass was moist. These nights were calm, and evaporation from grass, consequently, not copious. When evaporation, on cloudy nights, was assisted by wind, dew has never been anywhere observed by me. (Note.—The interval between the first appearance of dew in the afternoon on grass, in shaded places, and sunset, was formerly said by me, on the authority, however, only of a few observations, to be considerably (*Page* 244) greater than that between sunrise and the ceasing of the formation of dew upon grass in the morning. These observations were made on spots exposed during the greater part of the day to the sun. In such places the heat acquired from the sun by the uppermost layer of earth will be longer retained than that acquired by the grass, which will, therefore, be sufficiently cool soon after the heat of the day has declined, to condense a part of the vapour then copiously rising from the earth; whereas in the morning both less vapour will rise, the surface of the earth having now lost a great part of its heat, and a less proportion of that which does rise will be condensed by the grass, as the temperature of this body now more nearly approaches that of the ground, from first receiving the heat of the sun, reflected from the atmosphere and other substances.) Agreeably to another opinion, the dew found upon growing vegetables is the condensed vapour of the very plants on which it appears. But this also seems to me erroneous, for several reasons. Dew forms as copiously upon dead as upon living vegetable substances. The transpired humours of plants will be carried away by the wind which passes over them, when they are not sufficiently cold to condense the vapour contained in it, unless, which is almost never the case if mist does not already exist, the general mass of the atmosphere be incapable of receiving moisture in a pellucid form. Accordingly, on cloudy nights, when the air, consequently, can never be cooled more than a little below the point of repletion with moisture by bodies in (*Page* 245) contact with it, dew is never observed upon any plants that are elevated a few feet above the ground. If a plant has become, by radiating its heat to the heavens, so cold as to be enabled to bring the air in contact with it below the point of repletion with moisture, that which forms upon it from its own transpiration will not then, indeed, evaporate. But other moisture will, at the same time, be communicated by the atmosphere; and when the difference in the copiousness of these two sources is considered, it may, I think, be safely concluded that almost the whole of the dew which will afterwards form on the plant must be derived from the air, more especially when the coldness of a clear night, and the general inactivity of plants in the absence of light, both lessening their transpiration, are taken into account. An experiment, however, has been appealed to in proof that the dew of plants actually does originate from fluid transpired by them; that, namely, in which a plant, shut up in an air-tight case, becomes covered with moisture. But this experiment, if attentively examined, will be found to have little weight. First, the enclosed plant being exempt from the cold, which its own radiation would have produced in its natural situation, in a dewy night will transpire (*Page* 246) a greater quantity of fluid than a similar plant exposed at the same time in the open air. Again, the small quantity of air contained in the case must soon be replete with the moisture, after which the whole of what is further emitted by the plant will necessarily assume the form of a fluid, whatever may be the condition of the external atmosphere; whereas during the clearest night only a part of the smaller quantity of moisture emitted by the exposed plant will be condensed on its surface. In the last place, notwithstanding the circumstances which favour the appearance of moisture upon enclosed plants from their transpiration, still the quantity observed on them is said to be much less considerable than what is seen upon plants of the same kind exposed to the air for the same time during a calm and serene night. De Luc (*Page* 259) remarks that clouds frequently disappear soon after sunset. I have also

noticed that the air is then calmer; and that this calmness very commonly, if not always, precedes the dissipation of the clouds.

Thomson, Annals of Philosophy. (*B.* 1818, 2.)

Philo-chemicus Oxoniensis.

(*Page* 102) De Luc's and Howard's explanations of the suspension of clouds are (*Page* 103) not satisfactory. The quantity of moisture which the air is capable of dissolving must depend partly on the temperature and partly on the density of that fluid. Near the earth's surface the higher temperature of the air causes it to preserve a larger portion of aqueous vapour in an elastic form. In the most elevated regions, owing to the extreme rarity of the air, atmospheric pressure scarcely opposes any check to the natural tendency of water to assume an aeriform state, so that it remains in the form of vapour, independent, perhaps, of any chemical solution. Hence, as we ascend in the atmosphere, the quantity of moisture held by it in solution must go on diminishing, until we arrive at that point beyond which the effect of the diminished pressure predominates over that of its chilliness; so that from this point upwards the quantity of aqueous vapour goes on increasing. The medium point is the region of the clouds, which are known to occupy a certain height in the atmosphere, above which (*Page* 105) they rarely extend. Let us then suppose an ascending portion of air to have arrived at such a height that its diminished temperature no longer allows of its retaining the whole of the moisture it had dissolved when near the surface; the consequence will be that a portion of water is disengaged in the state of what is termed vesicular vapour, that is, holding intermixed with it a portion of atmospheric air. Now, as the air is considerably rarer at the height of two or three miles (the usual elevation of the clouds) than nearer the surface, it may easily happen that the watery vesicles, in the progress of their descent, meet at length with a stratum of such density as to be just equivalent to the weight of the vesicular vapour joined with that of the air intermixed with it; they will remain suspended until the air within becoming of nearly equal density with the atmosphere without, or the particles coalescing into larger drops, the whole becomes too heavy for the atmosphere to support. The presence of intermixed air seems confirmed by the hollow found in the centre of hailstones; and the flakes of snow, which fall so slowly through the air, owe their low specific gravity to the same cause. Cirri seem to be formed immediately from the disengagement of the vesicular vapour, and therefore to occupy that line of elevation at which the quantity (*Page* 106) of moisture held in an aeriform state is at its minimum; hence we see the reason why they continue for so long a time without having their density increased. Evaporation goes on from the upper surface, while the ascending portions of the air are adding to its bulk on the inferior; and unless the latter exceeds the former the cloud will remain stationary. But when the quantity of vapour disengaged exceeds what is carried off from it by evaporation, the vesicular vapour gravitates slowly downwards, and, increasing in bulk as it descends, constitutes the cumulus. It would appear, then, that the cumulus usually occupies that line of elevation at which the atmosphere is exactly equivalent to the weight of the vesicular vapour joined with that of the air intermixed with it.

[This is an amplification of ideas expressed at a much earlier date. See Notes, 1766. Saul, pp. 30, 31.]

1819.

Dalton, John. (*B.* 1819, 1.)

(*Page* 8.) From observations made at Manchester by myself, by Hutchinson at (*Page* 9) Liverpool, and by the Royal Society in London, it appears that from March (*Page* 10) to September the weight of the air is heavier than from September to March.

(*Page* 11.) This seems to depend on the declination of the sun. The means by which the effect is produced, I conceive, are these: the sun's action is constantly increasing the mass of aqueous vapour in the atmosphere during the period from the vernal to the autumnal equinox. That is, the whole mass of vapour existing in the air is daily increasing, notwithstanding the quantity precipitated. This fact is verified by the constant rise of the vapour-point till September, after which it commonly declines pretty rapidly. Now it is obvious that the addition of aqueous vapour to the atmosphere must add to the weight of the atmosphere, and this is, I imagine, the cause of the increase of its weight in that season. An opposite conclusion may be deduced from these premises, on the ground that, as aqueous vapour is specifically lighter than air, the more there is of it the less is the weight in any given volume of air of given elasticity. But the aqueous vapour at most constitutes but one-fiftieth part of the atmosphere, and any excess of this which may prevail in any one place cannot be supposed powerful enough to move the rest of the atmosphere towards any place where the vapour is deficient. Now we have no reason to believe that much intercourse takes place between the atmosphere of the northern and southern hemispheres. The great and unceasing currents of the air are between the equator and the polar regions, but that any large volumes of air cross the equator from one hemisphere to the other does not appear from any phenomena we are acquainted with. And if the air does not cross the equator, the vapour cannot, being so intimately blended with the air. Thus although there may be a constant pressure or tendency of (*Page* 13) the atmosphere in the northern hemisphere to invade that of the southern during our summer, or *vice versa* in winter; yet I conceive it never can be so effectual as to restore a perfect equilibrium during the season, but will leave an excess of vapour in one hemisphere unbalanced either by air or vapour of the opposite hemisphere. The (*Page* 24) condensation of vapour by cold will not explain the phenomena of rain. Dr. Hutton maintained that the quantity of vapour capable of entering into the air increases in a greater ratio than the temperature; and hence he infers that whenever two volumes of air of different temperatures are mixed together, each being previously saturated with vapour, a precipitation of a portion of vapour must ensue in consequence of the mean (*Page* 25) temperature not being able to support the mean quantity of vapour. In 1793 I missed the distinguishing feature of his theory. My opinion that the vapour was not in chemical union with the air, but was mechanically wafted along by its currents, was founded in part on Saussure's experiments showing that a cubic foot of dry air at 66° would imbibe 12 grains of water for its saturation. Now from experiments I was persuaded that this was nearly what would fill a cubic foot of empty space at 66°, and hence I concluded that the same quantity of vapour was required to saturate a given space whether it contained air or not. In 1801 I experimentally proved the (*Page* 27) truth of this inference. I also proved that the temperature increasing in an arithmetical ratio, the force of steam increased in a geometrical one. Hence Hutton's (*Page* 28) theory is no doubt the true one. The whole quantity of water in the atmosphere in January is usually about 3 inches, as appears from the dewpoint which is then about 32°. The force of vapour at that temperature is ·2 inch of mercury, i.e. 2·8 or 3 inches of water. The dewpoint in July is usually about 58° or 59°, corresponding to ·5 inch of mercury or 7 inches of water; the difference is 4 inches of water. Hence with the same amount of intermixture of currents the rain should be 4 inches less than the average in the former, and 4 inches above it in the latter period. In these estimations I assume that the atmosphere of steam is blended with the general atmosphere (*Page* 29) throughout in the same vertual [vertical] column, and subject to the common law of rarefaction in ascending.

1823.

Daniell, J. F. *Meteorological Essays and Observations.* 8vo. London. 1823. (*rvp.*)

(*Page* 49.) I now consider an atmosphere of unmixed aqueous vapour on a sphere of uniform temperature (32° F.) covered with water. Dalton has estimated the elastic (*Page* 51) force of steam at different temperatures. The density of the vapours must decrease in a geometrical progression for equal perpendicular distances, and the temperature will decline with it, but in a different ratio. At 10,000 feet it would be ·157 in., (*Page* 52) and the constituent temperature [dewpoint] 25°. The following shows the elasticity, density and temperature of the vapours at different elevations.

Height. Feet.	Elasticity. Inches.	Density.	Temperature of Vapour.
0	.2	1.0	32.0
5,000	.177	.89	28.5
10,000	.157	.79	25.0
15,000	.140	.708	22.0
20,000	.124	.636	19.0
25,000	.110	.577	16.0
30,000	.100	.518	13.0

With such an arrangement there would be perfect equilibrium, and consequently perfect rest all over the sphere. No precipitation or evaporation would take place, and the atmosphere would remain transparent. Such also would be the state to which an atmosphere would strive to attain, notwithstanding any obstacles which might be opposed to it. Hence we may also infer that if condensation were to take place in any part of such an atmosphere, evaporation must follow in other parts to maintain the balance of forces; and conversely that evaporation must be accompanied by precipitation. Should the temperature of the sphere rise gradually and equally over all its surface, the elasticity of the steam would increase with it, without disturbance; and following its own law of decrease for its different elevations, would remain perfectly (*Page* 53) transparent. In considering the second modification of circumstances, that, namely, of the temperature of the sphere, increasing from the poles to the equator, we must first observe that a pure unmixed atmosphere could not follow such a gradation. The elasticity of the whole would be determined by that of the lowest point; and the water would distil from the hottest point to the coldest with such a rapidity as to occasion strong ebullition at the former. The condensation of vapour may be affected, not only by decrease of temperature, but by increase of pressure; it is not necessary, therefore, that it should pass from the hottest to the coldest point to be precipitated, which would be a gradual process; but the elastic force arising from an increase of density at one extremity would instantly be felt at the other. For our present purpose we must imagine the passage of the vapour from one point to another to be so mechanically retarded as to enable it to assume the gradations due to the heat of the sphere. We may estimate the relative force and pressure of two of the perpendicular columns at different stations. The following table represents the state of the vapour at the equator, supposing the temperature 80° as before:

(*Page* 54.)

Feet.	Elasticity.	Density.	Temperature.
0	1.000	4.571	80.0
5,000	.897	4.115	76.5
10,000	.804	3.682	73.0
15,000	.722	3.356	70.0
20,000	.648	3.026	67.0
25,000	.581	2.723	63.0
30,000	.521	2.487	60.0

Comparing this with the last table, we observe that both the density and elasticity increase greatly with the temperature, and the consequence must be that the equatorial columns must press upon the polar throughout their length. The vapour will flow in a mass from the equator to the poles, and being necessarily condensed in its course will

return from the poles to the equator in the form of water. Great evaporation will constantly be going on at the latter stations and condensation at every other, so that the atmosphere, excepting at the equator, would be rendered turbid by perpetual clouds and rain. The temperature of the sphere would by this process soon become equalised, did (*Page* 55) not our hypothesis provide for its permanency; the equatorial parts would be quickly cooled by evaporation, and the polar warmed by the heat evolved during the condensation. It is worthy of attention that the elasticity of vapour increasing nearly in a geometrical proportion for equal increments of heat, the decrease of temperature in ascending in this atmosphere will be in arithmetical proportion only. The diminution is very nearly three degrees for every 5000 feet. Upon the hypothesis of the gradation of temperature before assumed, the following table will represent the corresponding elasticity and density of the vapour at the surface of the sphere for every ten degrees of latitude:—

	Elasticity. (E.)	Density. (D.)	Temp. (T.)
Poles.	.064	.34	0°
80°	.072	.38	3.2°
70°	.089	.466	9.6°
60°	.125	.611	19.2°
50°	.2	1.0	32°
40°	.351	1.7	48°
30°	.539	2.547	60.8°
20°	.731	3.403	70.4°
10°	.9	4.133	76.8°
Equator.	1.000	4.571	80°

(*Page* 56.) Under these circumstances the equatorial regions will remain perfectly transparent, while rains will continue to fall in every other situation in proportion to the densities of the respective places and the decrease of temperature, and the supply of vapour will be entirely kept up by the evaporation at the equator. The height of the barometer decreases rapidly towards the poles from 1 in. to .064 in., and the quantity of condensation is definite for each latitude; for the resistance to the passage of the vapour is supposed to be constant and equal. Let us now imagine that the temperature is raised to the level of that which adjoins; then condensation will cease at that particular place, evaporation will commence, and the atmosphere will become transparent. The quantity of water precipitated will be proportionally increased on the other side. If, on the contrary, the temperature be lowered to the standard of the latitude next above, the precipitation will be increased and the higher latitude will be cleared. The following table represents lat. 30° under these two conditions.

		Elasticity.	Density.	Temp.
40°	Cloudy.	.351	1.7	48°
	Clear.	.351	1.7	
30°	Clear.	.731	3.403	70.4
	Cloudy.	.351	1.7	
20°	Cloudy.	.731	3.403	70.4°
	Cloudy.	.731	3.403	70.4°

(*Page* 57.) Again, if the mechanical retardation of the flowing vapour which we imagined were subject to variation, the quantity of evaporation and precipitation would be proportionate to the velocity of its passage; thus, supposing the evaporation from a given surface at a given temperature and under a certain resistance to be three grains per minute, it would be increased to six grains with half the resistance. The changes at the surface affect the whole of the superincumbent columns equally and the temperature of the vapour follows its own law of decrease. But what will be the consequence if the vapour should be forced to adapt itself to a progression different from that of its own, and if, from some cause or other, the heat of the upper regions should diminish at a greater rate than is due to the natural gradation? Let us, for instance, suppose that the heat of the water upon the sphere is 80°, but that at the height of 5000 feet above the surface a temperature exists of 64.4°, which from that point follows the former decreasing scale. The water will have a tendency to throw off vapour of the same constituent heat as its own temperature, but the pressure above being rendered too little by the influence of the forced degree of cold to preserve the necessary elasticity below, the

atmosphere will only possess the tension due to the lower degree, that is to say, the con- (*Page* 58) stituent temperature will be only 67·9°. Evaporation must, therefore, ensue below, and its concomitant precipitation will take place above. The calculation of these effects has furnished the following tabular representation of their connection.

Height. Feet.	Elasticity.	Constant Temperature.	Sensible Temperature.	State of Atmosphere.
0	[*].673	[*]67.9	80	Clear.
5,000	[*].606	[*]64.4	[*]64.4	Cloudy.
10,000	.542	61.0	61.0	Clear.
15,000	.490	58.0	58.0	do.
20,000	.443	55.0	55.0	do.
25,000	.401	52.0	52.0	do.
30,000	.363	49.0	49.0	do.

[The [*] indicate asterisks added in the 1845 ed.]

The consequence of this situation of things will be that a cloud will be formed at the height named, for the atmosphere will be forced upward by the nascent [" spring of the " is an addition in 1845 ed.] vapour, and will be condensed at this point. The cloud, however, supposing the process to be sufficiently gradual, would not extend very far downwards, for the water during its precipitation would be redissolved [changed to "re-evaporated" in 1845 ed.] by the excess of heat in the lower regions, so that they might remain transparent and undisturbed. The ultimate effect would be that the temperature would be slowly equalised, and the balance of force restored. The water in its circulation backwards and forwards would act as a carrier of the heat which it would abstract from the lower part by its evaporation, and give out to the upper by its condensation. The atmosphere would thus gradually recover its state of equilibrium and repose. The upper regions, upon this supposition, remain clear, for (*Page* 61) there the regular gradation is undisturbed. We have already proposed the simple case of a sudden decrease of heat at one stage of its height by which condensation was produced; the elasticity was thereby reduced to the degree appropriate to that temperature at that elevation, and evaporation commenced from the surface. This evaporation was proportionate to the difference between the elasticity of the temperature of the sphere and the elasticity of the superincumbent mass. We will now suppose that the rapid decrease of temperature continues throughout the column, and that at the (*Page* 62) following heights it is forced to adapt itself to the annexed progression.

Height.	Temperature.
0	80°
5,000	64.4
10,000	48.4
15,000	31.4
20,000	12.8
25,000	— 7.6
30,000	—30.7

The elasticity could not then exceed .043 inch upon the surface; the evaporation would consequently be excessive and its force would almost amount to explosive violence; while the condensation above would be proportionate, and the precipitation would resemble a waterspout in its effects.

(To be continued.)

Scientific Union.

The rapid progress of science now going on is, in part, the result of the great increase in the number of workers. This is accompanied by a larger and larger host of scientific serials. The consequence is that the student finds an increasing difficulty in ascertaining what has been done, or is in process of being accomplished, not only in his own special line of study, but also, and more particularly, in such as do not immediately interest him. Every student finds, from time to time, that he has a desire for full information on subjects in these outlying sciences, for the purpose of throwing light upon his special studies. The state of literature is such that he is frequently daunted by the difficulties attending his research, or, if he perseveres, he finds a great deal of time unnecessarily wasted. The remedy for this is the focalisation of knowledge round a series of centres. The two main steps in the process are, first, collection, and, next, classification. It is with this ulterior object in view, that all persons interested in meteorology are earnestly asked to forward their names and addresses, particulars as to the work they have done in meteorological and other sciences, their present lines of study, ways in which help is desired, and any other items that may occur to them. These details will be classified, and, when the opportunity offers, selections from them will be published. The Conductor will exercise careful discretion in the selection, as also in the use he may make of the more private details. The first list will be published in November, 1883; but correspondents are requested to send in answers soon, in order to allow of ample time for their classification, and for their utilisation in private correspondence in the interests of correspondents.

In order to prevent any misconception, it may be stated that the Conductor's object is solely to promote scientific union, and is no way intended to be of a charitable nature in any pecuniary sense. If there is a sufficient response to these requests, the same line of proceeding will hereafter be suggested, from time to time, for the students in other branches of science.

Newspapers and scientific journals of all countries, willing to help in this matter, are asked to make the above requests known to their readers.

Address, Conductor, "Scientific Roll" office, 7 Red Lion Court, Fleet Street, London, E.C.

In the hopes of promoting Scientific union, attention is asked to the circulars issued by the Conference of Delegates of Scientific Societies reprinted below, as also to the sets of questions asked by Sergeant J. P. Finley, of the United States Signal Service, which are reprinted farther on, under 'The Scientific Enquirer.' The observations and tables in the circulars of the Conference are intended to apply only to the British Isles, and

Sergeant Finley's questions apply strictly to the United States. As it is desirable that the results obtained by the workers in these areas should be comparable with those obtained in other regions, a special request is made for modifications of these lists and sets of questions, adapting them for each special district, as also for the lists, circulars, and methods of procedure which have been adopted and acted upon in all parts of the world. Any local Scientific Society which has not received the circular of the Conference is requested to communicate with Mr. Fordham, or with the Conductor of the "Scientific Roll."

CONFERENCE OF DELEGATES FROM SCIENTIFIC SOCIETIES.

Held Annually during the Meeting of the British Association.

To the Secretary of the

Sir,

I enclose a copy of the Minutes of the Proceedings of the Conference held at York, on September 6th, 1881.

You will see that a Committee was then appointed, with instructions (1) to "take steps to have the Conference of Delegates recognised by the Council of the British Association," and (2) "to send out a circular to the various local Scientific Societies, pointing out the work undertaken by the Committees of the British Association, and the valuable aid which may be given by these Societies in that and other scientific work."

The Committee have prepared and now enclose a circular drawn up in accordance with their instructions, and you are requested to bring it and the other enclosures under the notice of your Society.

There are only three Committees of the British Association whose investigations seem likely to benefit through the assistance of local Scientific Societies, but the Committee have selected some other subjects which may usefully engage the attention of such Societies.

The Committee will be glad to have any criticisms or remarks on the subject-matter of the circular, and they will be obliged if you will inform them should your Society set on foot any regular system of recording observations on any of the points referred to.

The Third Conference of Delegates will be held during the Meeting of the British Association at Southampton, in August. The names of Delegates representing your Society may be sent to me, and notice of the time and place of the Conference will be left for them at the post office, in the reception room, as soon as possible after the commencement of the Meeting.

It is necessary, if your Society desires to avail itself of the privilege conferred by the Rule of the British Association given below,* and in order that your Delegates should have the right to sit on the General Committee, and that their names should appear in the Journal, that you should make a formal claim to the Assistant Secretary, 22, Albemarle Street, London, W., some little time before the date fixed for the meeting.

Yours faithfully,

H. GEORGE FORDHAM,

Odsey Grange, Royston, Cambs.,

24*th April*, 1882. *Hon. Sec. to the Committee.*

* "General Committee—Class B. Temporary Members." "1. The President for the time being of any Scientific Society publishing Transactions, or, in his absence, a delegate representing him; and the Secretary of such Society. Claims under this rule to be sent to the Assistant Secretary before the opening of the Meeting." Note.—The Delegate must be a *Member* (not *Associate*) of the British Association.

CIRCULAR REFERRING TO SUBJECTS RECOMMENDED FOR INVESTIGATION BY LOCAL SCIENTIFIC SOCIETIES.

I.—COMMITTEES OF THE BRITISH ASSOCIATION.

The work of the three following Committees is of a character to receive valuable help from local Scientific Societies. It will be seen that a large number of observers, spread over the whole country, is necessary for carrying on the investigations for which the Committees are appointed.

Attention is therefore called to the objects which these Committees have in view; but, as the limits of this circular do not permit of the insertion of full particulars of the methods of observation employed by the Committees, Societies or individuals willing to assist them should communicate with the Secretaries (whose names and addresses are given), and to whom Reports should be sent.

1.—Underground Waters Committee.

Sec.:—C. E. De Rance, F.G.S., 28, Jermyn Street, London, S.W.

Object.—To investigate the circulation of the Underground Waters in England and Wales, and the quantity and character of the waters supplied to various towns and districts.

Records of the heights of the water in wells, with particulars of the variations of level at different periods, are required, as well as notes on the character of the water, and particulars of the formations from which it is derived.

2.—Erratic Block Committee.

Sec.:—Rev. H. W. Crosskey, F.G.S., 28, George Road, Birmingham.

Object.—To record the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, to report other matters of interest connected with the same, and to take measures for their preservation.

It is obvious that to obtain a record of the boulders of Great Britain and Ireland at all approaching completeness, a large amount of local assistance must be relied on. And as, at the same time, the value of the deductions to be made from the information collected by the Committee depends almost entirely on their investigations covering the whole area under consideration, the Committee are obliged to appeal to local Societies and local observers for help.

Boulders are scattered over large districts of the country, particulars concerning them can easily be noted, and as they are continually being destroyed, or removed from their original sites, it is very desirable that records should be obtained as early as possible. By the accumulation of information from all parts of the country, and by its careful arrangement and examination, the Committee hope to arrive at data which will be of material assistance in the study of the history of the Glacial Period.

The investigations of this Committee do not extend to Scotland; the Royal Society of Edinburgh having appointed a "Boulder Committee" for that country. Of the Scotch Committee, Mr. D. Milne Home, M.A., F.R.S.E., F.G.S., 10, York Place, Edinburgh, is the Convener.

3.—Underground Temperature Committee.

Sec.:—Prof. J. D. Everett, M.A., D.C.L., F.R.S., Rushmere, Malone Road, Belfast.

Object.—To investigate the rate of increase of Underground Temperature downwards in various localities of dry land and under water.

The Committee undertake the determination of temperature at great depths below the earth's surface, in mines, deep wells, artesian borings, etc. Special thermometers are lent by the Committee to observers.

II.—INVESTIGATIONS CONDUCTED BY INDIVIDUAL OBSERVERS OR SOCIETIES.

Information relating to the following subjects is collected by the observers or Societies referred to, and further particulars as to the method of observation, etc., will be furnished, on application, by them. The subjects mentioned are all very suitable for investigation by local Scientific Societies.

1.—Rainfall.

G. J. Symons, F.R.S., 62, Camden Square, London, N.W.

The pamphlet sent herewith (Enclosure 1) sufficiently explains the nature and value of the work undertaken by Mr. Symons. The more widely the knowledge of that work and of its importance is spread, the greater will be the increase in the number of observers, and the value of the ultimate results will be correspondingly enhanced.

The Committee would recommend the publication, locally, of observations extended over a limited area (such as a county), and at frequent intervals, as being very effective in arousing local interest in the subject. A copy of the table published monthly in Hertfordshire, in most of the local newspapers, is enclosed (Enclosure 2), as a specimen of what may be done without much trouble or expense. In this table the various stations are grouped in the river-basins of the county, and the average rainfall of each of these areas is inserted. The Hertfordshire Natural History Society and Field Club publishes also annually in its 'Transactions' a considerable amount of information on the Rainfall, and has obtained a substantial increase in the number of observers in the county. It is suggested that other local Societies should take similar steps for the encouragement of rainfall observation.

(*Enclosure* 1.)

ARRANGEMENTS FOR THE SYSTEMATIC OBSERVATION AND RECORD OF THE RAINFALL OF THE BRITISH ISLES.

Introductory and Historical.—I cannot help this section appearing to be egotistical; the rainfall organisation being entirely my own creation, it is impossible for it to be otherwise.

In the early part of the year 1859 I began collecting copies of records of the fall of rain, and early in 1861 wrote to all the observers of whom I was then aware, and asked them to send me all the records for the year 1860 that they could. I received 168 returns, and printed a table showing the total fall of all those places, being a larger number than had ever been classed together before. This publication gave a stimulus to observers, and from that time onwards their number has steadily increased until it now exceeds 2000.

The amount of information published has increased even more, for whereas at first I printed only the total annual fall, I now publish essays on various branches of rainfall enquiry, and full abstracts of the most remarkable falls in short periods (ten minutes, half-an-hour, and so on), the heaviest falls in one day, tables of the monthly fall at several hundred stations, and, in short, give all the information which I can collect and which it seems expedient to print.

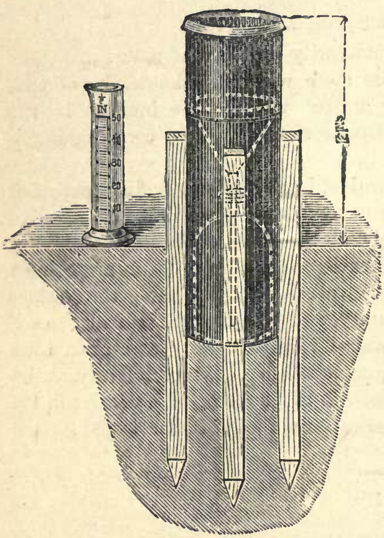
From the foregoing it will be evident that the compilation of the present annual volume (of which the short title is "British Rainfall, 1877," &c.) is a very serious labour. The mere checking of two thousand returns takes a long time, and so does the due arrangement of the

various facts reported, and by no means the least onerous matter is ensuring the accuracy of the printing of the whole.

During the first few years I not only gave my own time gratuitously to the work, but also bore all the cost of postages and of printing. It soon, however, became far too costly for me to bear it all, and my correspondents most kindly offered to share it with me. In 1865 the price of the annual volume was fixed at five shillings, and, although the size and cost of the volume have since largely increased, no rise has been made in the price. There are two reasons for this: (1) Because if the book could not be compiled without the help of observers, they ought to be allowed to have it as cheaply as possible; (2) Because a small number of the observers (about 300, whose subscriptions are duly published) contribute annual sums varying from one to ten guineas towards the general expenses of the work.

The existing state of matters is, therefore, shortly as follows. There are about 2000 persons, well spread over England and Wales, Scotland and Ireland, each of whom is, I hope, strictly obeying the rules on page 5. To each of them I send on December 31st each year, blank forms for them to return to me filled with the facts observed by them. At the same time I send a list of the various publications, and invite such pecuniary aid as it may be agreeable to them to send.

I ought, perhaps, to say what becomes of the subscriptions. I will mention some of the outlets. (1) There are nearly a thousand observers whose returns have to be collected, examined, discussed, and printed, who do not contribute sixpence towards the cost thereof. (2) In some localities it is impossible to obtain volunteer observers, and there the observers receive regular salaries. (3) The mass of office work, correspondence, &c., is far beyond what I can myself accomplish; two regular assistants are, therefore, employed, and besides that, considerable sums are paid for extra assistance at times of pressure. (4) The expenditure for printing and postages is very large.



In addition to the annual volume, I publish a monthly periodical, *Symons's Monthly Meteorological Magazine*, giving, in addition to a full chronicle of the progress of meteorology, details of rainfall at about 100 stations. This is sent free to subscribers.

It may, perhaps, be added that it always affords me pleasure to reciprocate, as far as possible, the assistance which the observers render to me, either by affording them meteorological information, data as to the height of their stations above sea level, or advice as to the purchase of instruments.

In short, the state of the case is this: I have given myself up to the collection of statistics of rainfall—old ones and current ones; I invite everybody to help me, both with observations and funds, and I promise, in return, to render to all my correspondents all the help that is in my power.

Patterns of Rain Gauges, and where to buy them.—This is not a pleasant section to write, for there is considerable jealousy among the manufacturers, and I am almost certain to be accused of favouritism by some one. However, I have never patented any pattern of rain gauge, and, therefore, leave the field open to all.

Upon one point it is necessary to be despotic, viz., that amateurs never try to make their own gauges; they are almost certain to go wrong in some respect, and nothing is more vexing, both to the observers and to myself, than for it to be discovered, after observations have been recorded for a long time, that the labour of years is vitiated by an inaccurate instrument.

For use in ordinary localities I think the annexed is the best pattern; it is known as the Snowdon gauge, it is five inches in diameter, is easily fixed by four stakes as shown; the glass jar when filled up to the top division holds 0.50 in., or half an inch, the bottle holds about three inches of rain, and, of course, in the very rare case of the fall exceeding that, the excess is saved by the can, and must be carefully measured. If made in japanned tin these cost from 16s. to 20s., but they are much stronger, and more durable, if made in copper, when they cost from 21s. to 30s. Negretti's have just brought out a very stout pattern, in galvanized iron, at a still lower price. Where cost is no object, it is, by some, thought better to have a rather larger gauge, viz., eight inches diameter, costing from £2 to £3, but I do not advise it.

Snowdon pattern rain gauges can, no doubt, be obtained from any optician, but it may be convenient to give, in alphabetical order, the names and addresses of a few of the principal makers:—

CASELLA, L., 147, Holborn Bars, E.C.
HICKS, J. J., Hatton Garden, E.C.

NEGRETTI & ZAMBRA, Holborn Viaduct and Cornhill, E.C.
PASTORELLI, F., 10, New Bond Street.

Testing.—Wherever, and of whomsoever, rain gauges may be bought, it is very desirable that the purchaser should insist upon having certificates of their accuracy. Rain gauges are examined, and certificates issued, by Kew Observatory, and by myself, the charge in each case is the same, namely, 2s. 6d.

Blank Forms.—All blank forms required for returns to myself, and additional ones wherever desired, are supplied gratuitously, and even those sold are charged at little more than their actual cost.

Change of Residence.—Each observer is requested to decide upon a specific name for his station, and to notify immediately any change in the position of the gauge or the discontinuance of his record.

SUGGESTIONS FOR SECURING UNIFORMITY OF PRACTICE AMONG RAINFALL OBSERVERS.

I.—SITE.—A rain gauge should not be set on a slope or terrace, but on a level piece of ground, at a distance from shrubs, trees, walls, and buildings; at the very least, as many feet from their base as they are in height. Tall-growing flowers, vegetables, and bushes must be kept away from the gauge. If a thoroughly clear site cannot be obtained, shelter is most endurable from N.W., N., and E., less so from S., S.E., and W., and not at all from S.W. or N.E.

II.—OLD GAUGES.—Old established gauges should not be moved, nor their registration discontinued, until at least two years after a new one has been in operation, otherwise the continuity of the register will be irreparably destroyed. Both the old and the new ones must be registered at the same time, and the results recorded for comparison.

III.—LEVEL AND FIXING.—The funnel of a rain gauge must be set quite level, and so firmly fixed, that it will remain so in spite of any gale of wind or ordinary circumstance. Its correctness in this respect should be tested from time to time.

IV.—HEIGHT.—The funnel of gauges newly placed should be 1 ft. above grass. Information respecting height above sea level may be obtained from the editor.

V.—RUST.—If the funnel of a japanned gauge becomes so oxidised as to retain the rain in its pores, or threatens to become rusty, it should have a coat of gas tar, or japan black, or a fresh funnel of zinc or copper should be provided.

VI.—FLOAT GAUGES.—If the measuring rod is detached from the float, it should never be left in the gauge. If it is attached to the float, it should be pegged or tied down, and only allowed to rise to its proper position at the time of reading. To allow for the weight of the float and rod, these gauges are generally so constructed as to show 0 only when a small amount of water is left in them. Care must always be taken to set the rod to the zero or 0.

VII.—CAN AND BOTTLE GAUGES.—The measuring glass should always be held upright; the reading is to be taken midway between the two apparent surfaces of the water.

VIII.—TIME OF READING.—Nine a.m. daily; if taken only monthly, then 9 a.m. on the 1st.

IX.—DATE OF ENTRY.—The amount measured at 9 a.m. on any day is to be set against the previous one; because the amount registered at 9 a.m. of, say, 17th, contains the fall during 15 hours of the 16th and only 9 hours of the 17th. (*This rule has been approved by the Meteorological Societies of England and Scotland, cannot be altered, and is particularly commended to the notice of observers.*)

X.—MODE OF ENTRY.—If less than one-tenth (·10) has fallen, the cypher must *always* be prefixed; thus, if the measure is full up to the seventh line, it must be entered as ·07, that is, no inches, no tenths, and seven hundredths. For the sake of clearness, it has been found necessary to lay down an invariable rule that there shall always be two figures to the right of the decimal point. If there be only one figure, as in the case of one-tenth of an inch (usually written ·1) a cypher must be added, making it ·10. Neglect of this rule causes much inconvenience. All columns should be cast *twice*—once up and once down, so as to avoid the same error being made twice. When there is no rain, a line should be drawn rather than cyphers inserted.

XI.—CAUTION.—The amount should always be written down before the water is thrown away.

XII.—SMALL QUANTITIES.—The unit of measurement being ·01, observers whose gauges are sufficiently delicate to show less than that, are, if the amount is under ·005, to throw it away; if it is ·005 to ·010 inclusive, they are to enter it as ·01.

XIII.—ABSENCE.—Every observer should train some one as an assistant; but where this is not possible, instructions should be given that the gauge should be emptied at 9 a.m. on the 1st of the month, and the water bottled, labelled, and tightly corked, to await the observer's return.

XIV.—HEAVY RAINS.—When very heavy rains occur, it is desirable to measure immediately on their termination, and it will be found a safe plan after measuring to return the water to the gauge, so that the morning registration will not be interfered with. Of course if there is the slightest doubt as to the gauge holding all that falls, it must be emptied, the amount being *previously* written down.

XV.—Snow.—In snow three methods may be adopted; it is well to try them all. (1) Melt what is caught in the funnel by adding to the snow a previously ascertained quantity of warm water, and then deducting this quantity from the total measurement, enter the residue as rain. (2) Select a place where the snow has not drifted, invert the funnel, and turning it round, lift and melt what is enclosed. (3) Measure with a rule the average depth of snow, and take one-twelfth as the equivalent of water. This being a very rough method, is not to be adopted if it can be avoided. Some observers use in snowy weather a cylinder of the same diameter as the rain gauge, and of considerable depth. If the wind is at all rough, all the snow is blown out of a flat-funnelled rain gauge. Snowdon pattern gauges are much the best.

XVI.—Overflow.—It would seem needless to caution observers on this head, but as a recent foreign table contains *six instances on one day* in which gauges were allowed to run over, it is evidently necessary that British observers should be on the alert. It is not desirable to purchase any new gauge of which the capacity is less than four inches.

XVII.—Second Gauges.—It is desirable that observers should have two gauges, and that one of them should be capable of holding eight inches of rain. One of the gauges should be registered daily, the other weekly or monthly as preferred, but always on the 1st of each month. By this means a thorough check is kept on accidental errors in the entries, which is not the case if *both* are read daily.

XVIII.—Dew and Fog.—Small amounts of water are at times deposited in rain gauges by fog and dew; they should be added to the amount of rainfall, because (1) they "tend to water the earth and nourish the streams;" and not for that reason only, but (2) "because in many cases the rain gauges can only be visited monthly, and it would then obviously be impossible to separate the yield of snow, rain, &c.; therefore, for the sake of uniformity, all must be taken together."

XIX.—Doubtful Entries.—Whenever there is the least doubt respecting the accuracy of any observation, the entry should be marked with a ?, and the reason stated for its being placed there.

XX.—Breakage.—The Editor has no desire to supply rain gauges or glasses, or in any way to undertake, or interfere with, that which is the business of opticians; but the continuity and permanent accuracy of the records of his correspondents is to him of such importance, that he deems it advisable to announce that any assistance in his power is always at their service.

62, *Camden Square, London, N.W.* G. J. Symons.

[For Rainfall in Herts (*Enclosure* 2), see next page.]

2.—Periodical Natural Phenomena.

Assistant Secretary, Meteorological Society, 30, Great George Street, London, S.W.

Rev. T. A. Preston, M.A., F.L.S., The Green, Marlborough, Wilts.

The appended list of 60 species recommended for observation (p. 229) is a selection from the 100 species of which the list of the Meteorological Society consists, of which a copy is enclosed (Enclosure 3). The phenomena to be observed are given in the probable order of occurrence as deduced from the mean of six years' observations (1876–81) by members of the Hertfordshire Natural History Society. Observers may, if they prefer to do so, adopt the more extensive list of the Meteorological Society, or they may confine their attention to the 25 species of which the English names are here printed in capitals.

There are at present over 40 observers, who record facts coming under this heading, and it is very desirable that the number should be greatly extended, so that ultimately no part of the county may be without observers.

Observers are referred for further information to the following:—

'Instructions for the Observation of Phenological Phenomena.' London: Williams and Strahan. 1875. Price 6*d*. (Also to be had at the office of the Meteorological Society.)

"On the Observation of Periodical Natural Phenomena," by John Hopkinson, F.L.S.; with notes on the Plants to be observed, by the Rev. W. M. Hind, LL.D.; on the Insects, by Arthur Cottam; and on the Birds, by J. E. Harting, F.L.S., in 'Trans. Watford Nat. Hist. Soc.,' vol. i., part 2. London: David Bogue. 1875. Price 1s.

(*Enclosure* 2.)

RAINFALL IN HERTS.—For the month of March, 1882.

Rainfall in River Districts.			Station.	Above Sea Level.	Depth of Rain.	Diffnce. from Mean 1870–79.	Greatest fall in 24 hours.	Date.	Wet days.
THAMES 1·41	THAME 1·50	Upper Thame 1·50	*Aylesbury* (*Bucks*)	280	†1·50	— ·21	·60	25th	7
	COLNE 1·52	Upper Colne							
		Ver 1·45	*Kensworth*	600	1·33	— ·42	·46	25th	9
			Harpenden, Rothamsted	402	1·57	— ·18	·63	25th	15
		Gade and Bulborne 1·58	*Cowroast*	345	1·70	— ·05	·50	25th	13
			Berkhampstead	370	1·60	— ·15	·65	25th	10
			Gt. Gaddesden	426	1·35	— ·40	·61	25th	14
			Nash Mills	237	1·66	— ·09	·68	25th	14
		Chess							
		Lower Colne 1·49	*Watford, Watford House*	240	2·42?	+ ·67	·81	25th	14
			„ *Wansford House*	225	1·59	— ·16	·65	25th	14
			Bushey Heath	480	1·39	— ·36	·61	25th	12
			Rickmansworth, Moor Park	340	1·50	— ·25	·72	25th	14
	BRENT	Upper Brent.							
	LEA 1·32	Upper Lea 1·39	*Bayfordbury*	250	1·39	— ·23	·71	25th	12
		Mimram 1·07	*Welwyn*	230	·97	— ·65	·20	1st	14
			Datchworth	357	1·17	— ·45	·62	28th	8
		Beane 1·57	*Knebworth*	391	1·57	— ·05	·73	25th	13
		Rib 1·16	*Therfield*	500?	1·20	— ·42	·50	25th	11
			Throcking	484	1·12	— ·50	·56	25th	11
		Ash 1·35	*Much Hadham*	220	1·32	— ·30	·77	25th	8
			Ware, Fanham's Hall	235	1·38	— ·24	·65	25th	11
		Stort 1·37	*Stansted* (*Essex*)	240	†1·52	— ·10	·71	25th	8
			Harlow, Moor Hall (*Essex*)	273	†1·23	— ·39	·62	25th	8
		Lower Lea 1·42	*Hoddesdon*	147	1·47	— ·15	·91	25th	14
			Waltham Abbey (*Essex*)	82	†1·35	— ·27	·73	25th	7
			Southgate	240	1·44	— ·18	·65	25th	17
OUSE 1·20	IVEL 1·20	Hiz 1·22	*Hitchin*	238	1·15	— ·33	·57	25th	12
			„ *High Down*	422	1·29	— ·19	·58	25th	9
		Upper Ivel 1·17	*Stotfold* (*Beds.*)	220	†1·17	— ·31	·51	25th	13
	CAM 1·19	Rhee 1·19	*Odsey* (*Cambs.*)	264	1·15	— ·27	·56	25th	13
			Royston	269	1·23	— ·19	·62	25th	11
Mean for the County			......	......	1·37	— ·29			11

† Not taken into consideration in determining the County Mean Fall. + signifies above, — below the mean.

N.B.—One inch of rain represents 101 tons of water per acre. A wet day is one on which 0·01 in. or more falls.

Mean Rainfall (1870–79) for the month in River Districts, Thame 1·71; Colne 1·75; Brent [no observation]; Lea 1·62; Ivel 1·48; Cam 1·42.

C. W. HARVEY, F.M.S., *Throcking Rectory, Buntingford, Herts.*

[Reprinted from *The Herts. and Cambs. Reporter*, 21st April.]

3.—INJURIOUS INSECTS.

MISS E. A. ORMEROD, F.M.S., Dunster Lodge, Spring Grove, Isleworth, Middlesex.

The appearance of any of the Insects in the appended list (p. 228) in unusual numbers, any injuries done by them, and the degree of success which has attended any methods of prevention which have been tried, may be recorded and communicated to Miss Ormerod, by whom this list has been compiled, and who will forward on application forms on which to record observations.

Observers are referred for full information, instructions, and illustrations of the insects, to the following:—

'A Manual of Injurious Insects,' by Eleanor A. Ormerod. London: W. Swan Sonnenschein and Co. 1881. Price 3*s*.

"Notes for Observations of Injurious Insects," by the same, in 'Trans. Watford Nat. Hist. Soc.,' vol. ii., part 2. London: David Bogue. 1878. Price 1s. 6*d.*

'Report of Observations of Injurious Insects during the year 1881,' by the same. London: W. Swan Sonnenschein and Co. 1882. Price 1s. 6*d.* Previous Reports have been published under the title of 'Notes of Observations of Injurious Insects.' 1878–81.

Selected List of Periodical Natural Phenomena, in the probable Order of Occurrence.

JANUARY.

Song-thrush (*Turdus musicus*) sg.
Skylark (*Alauda arvensis*) sg.
SNOWDROP (*Galanthus nivalis*) fl.
Honey-bee (*Apis mellifica*) ap.

FEBRUARY.

ROOK (*Corvus frugilegus*) builds.
Sweet Violet (*Viola odorata*) fl.
COLTSFOOT (*Tussilago farfara*) fl.
Dog's Mercury (*Mercurialis perennis*) fl.

MARCH.

PILEWORT (*Ranunculus ficaria*) fl.
Wych-elm (*Ulmus montana*) fl.
DAFFODIL (*Narcissus pseudo-narcissus*) fl.
Barren Strawberry (*Potentilla fragariastrum*) fl.
Common Frog (*Rana temporaria*) spawns.
WOOD-ANEMONE (*Anemone nemorosa*) fl.
COWSLIP (*Primula veris*) fl.
MARSH-MARIGOLD (*Caltha palustris*) fl.
BLACKTHORN (*Prunus spinosa*) fl.
Small white Butterfly (*Pieris rapæ*) ap.
Ground-ivy (*Nepeta glechoma*) fl.
GREATER STITCHWORT (*Stellaria holostea*) fl.

APRIL.

Wild Chervil (*Anthriscus sylvestris*) fl.
SWALLOW (*Hirundo rustica*) first seen; last seen (October).
Cuckoo-flower (*Cardamine pratensis*) fl.
NIGHTINGALE (*Daulias luscinia*) sg.
CUCKOO (*Cuculus canorus*) first heard.
BLUE-BELL (*Endymion nutans*) fl.
Large white Butterfly (*Pieris brassicæ*) ap.
Ribwort-plantain (*Plantago lanceolata*) fl.
Upright Crowfoot (*Ranunculus acris*) fl.
Germander-speedwell (*Veronica chamædrys*) fl.
HERB-ROBERT (*Geranium robertianum*) fl.
Bush-vetch (*Vicia sepium*) fl.

MAY.

Creeping Bugle (*Ajuga reptans*) fl.
MILKWORT (*Polygala vulgaris*) fl.
SWIFT (*Cypselus apus*) first seen; last seen (August).
Cleavers (*Galium aparine*) fl.
Silver-weed (*Potentilla anserina*) fl.
DUTCH-CLOVER (*Trifolium repens*) fl.
Mouse-ear (*Hieracium pilosella*) fl.
OX-EYE (*Chrysanthemum leucanthemum*) fl.
Flycatcher (*Muscicapa grisola*) first seen; last seen (August).
Bird's-foot Trefoil (*Lotus corniculatus*) fl.
RED POPPY (*Papaver rhœas*) fl.
Ragged Robin (*Lychnis flos-cuculi*) fl.

JUNE.

YELLOW IRIS (*Iris pseudacorus*) fl.
Meadow-vetchling (*Lathyrus pratensis*) fl.
Spotted Orchis (*Orchis maculata*) fl.
Dog-rose (*Rosa canina*) fl.
COMMON MALLOW (*Malva sylvestris*) fl.
Hedge-woundwort (*Stachys sylvatica*) fl.
Wild Thyme (*Thymus serpyllum*) fl.
Broad Willow-herb (*Epilobium montanum*) fl.
Field-thistle (*Carduus arvensis*) fl.
Meadow-sweet (*Spiræa ulmaria*) fl.
BLACK KNAPWEED (*Centaurea nigra*) fl.
MILFOIL (*Achillea millefolium*) fl.

JULY.

Tufted Vetch (*Vicia cracca*) fl.
Yellow Bedstraw (*Galium verum*) fl.
Ragwort (*Senecio jacobæa*) fl.
HAIR-BELL (*Campanula rotundifolia*) fl.

ap.—first appears; fl.—flowers open; sg.—song first heard.

List of Injurious Insects, observations of which are specially desired.

INJURIOUS TO FIELD AND GARDEN CROPS.

1. Silver Y Moth (*Plusia gamma*).
2. Black Weevil (*Otiorhynchus sulcatus*).
3. Pea Weevil (*Sitones lineatus*).
4. Wire-worm Beetle (*Agriotes lineatus*).
5. Crane Fly (*Tipula oleracea*).
6. Spotted Crane Fly (*Tipula maculosa*).
7. Onion Fly (*Anthomyia ceparum*).
8. Celery Fly (*Tephritis onopordinis*)
9. Carrot Fly (*Psila rosæ*).
10. Bean Aphis, Collier (*Aphis rumicis*).

To Cabbages and Turnips.

11. Cabbage Butterfly (*Pieris brassicæ*).
12. Cabbage Moth (*Mamestra brassicæ*).
13. Turnip Moth (*Agrotis segetum*).
14. Turnip Fly (*Phyllotreta undulata*).
15. Turnip Sawfly (*Athalia spinarum*).
16. Turnip Aphis (*Aphis rapæ*).

To Corn.

17. Corn Sawfly (*Cephus pygmæus*).
18. Wheat Midge (*Cecidomyia tritici*).
19. Corn Fly (*Chlorops tæniopus*).
20. Wheat Aphis (*Aphis granaria*).

INJURIOUS TO TIMBER TREES AND FRUIT.

21. Goat Moth (*Cossus ligniperda*).
22. Leopard Moth (*Zeuzera æsculi*).
23. Lackey Moth (*Bombyx neustria*).
24. Small Ermine Moth (*Yponomeuta padellus*).
25. Magpie Moth (*Abraxas grossulariata*).
26. Apple Weevil (*Anthonomus pomorum*).
27. Pear-tree Slug (*Eriocampa adumbrata*).
28. Gooseberry Sawfly (*Nematis ribesii*).

To Pine Trees.

29. Giant Sirex (*Sirex gigas*).
30. Pine-bud Tortrix (*Retinia turionana*)
31. Fir Weevil (*Hylobius abietis*).
32. Pine Beetle (*Hylurgus piniperda*).

Observations of any other Insects are also desirable.

(*Enclosure* 3.)

THE METEOROLOGICAL SOCIETY.

Phenological Observations taken at   during   188

PLANTS.

	First Flower.	Full Flower.		First Flower.	Full Flower.
1 ANEMONE NEMOROSA (Wood Anemone)			19 *Vicia cracca* (Tufted Vetch)		
2 RANUNCULUS FICARIA (Pilewort—Lesser Celandine)			20 „ *sepium* (Bush Vetch)		
3 *Ranunculus acris* (Upright Crowfoot)			21 *Lathyrus pratensis* (Meadow Vetchling)		
4 CALTHA PALUSTRIS (Marsh Marigold)			22 PRUNUS SPINOSA (Sloe—Black-thorn)		
5 *Papaver rhœas* (Red Poppy)			23 *Spiræa ulmaria* (Meadow-sweet)		
6 *Cardamine hirsuta* (Hairy Bitter-Cress)			24 *Potentilla anserina* (Silver-weed)		
7 *Cardamine pratensis* (Cuckoo-flower—Lady's Smock)			25 *Potentilla fragariastrum* (Barren Strawberry)		
8 *Draba verna* (Whitlow-Grass)			26 *Rosa canina* (Dog Rose)		
9 *Viola odorata* (Sweet Violet)			27 *Epilobium hirsutum* (Great Hairy Willow-herb)		
10 *Polygala vulgaris* (Milkwort)			28 *Epilobium montanum* (Broad Willow-herb)		
11 *Lychnis flos-cuculi* (Ragged Robin)			29 *Angelica sylvestris* (Wild Angelica)		
12 *Stellaria holostea* (Greater Stitchwort)			30 *Anthriscus sylvestris* (Cow Chervil)		
13 MALVA SYLVESTRIS (Common Mallow)			31 HEDERA HELIX (Ivy)		
14 *Hypericum tetrapterum* (Square St. John's Wort)			32 *Galium aparine* (Cleavers)		
15 *Hypericum pulchrum* (Upright St. John's Wort)			33 „ *verum* (Yellow Bed-straw)		
16 GERANIUM ROBERTIANUM (Herb Robert)			34 *Dipsacus sylvestris* (Teasel)		
17 TRIFOLIUM REPENS (Dutch Clover)			35 *Scabiosa succisa* (Devil's-bit)		
18 *Lotus corniculatus* (Bird's Foot Trefoil)			36 *Petasites vulgaris* (Butter-bur)		
			37 TUSSILAGO FARFARA (Colts-foot)		
			38 ACHILLEA MILLEFOLIUM (Milfoil; Yarrow)		

PLANTS (*continued*).

	First Flower.	Full Flower.
39 *Chrysanthemum leucanthemum* (Oxeye)		
40 *Artemisia vulgaris* (Mugwort)		
41 *Senecio jacobœa* (Rag-wort)		
42 CENTAUREA NIGRA (Black Knap-weed)		
43 *Carduus lanceolatus* (Spear-Thistle)		
44 *Carduus arvensis* (Field-Thistle)		
45 *Sonchus arvensis* (Corn Sow-Thistle)		
46 *Hieracium pilosella* (Mouse-ear Hawkweed)		
47 CAMPANULA ROTUNDIFOLIA (Hair-bell)		
48 *Gentiana campestris* (Field Gentian)		
49 CONVOLVULUS SEPIUM (Greater Bindweed)		
50 *Symphytum officinale* (Comfrey)		
51 *Pedicularis sylvatica* (Red Rattle)		
52 *Veronica chamœdrys* (Germander Speedwell)		
53 *Veronica hederifolia* (Ivy-leaved Speedwell)		
54 *Mentha aquatica* (Water-Mint)		
55 *Thymus serpyllum* (Wild Thyme)		
56 *Prunella vulgaris* (Self-heal)		
57 *Nepeta glechoma* (Ground Ivy)		
58 *Galeopsis tetrahit* (Hemp-nettle)		
59 *Stachys sylvatica* (Hedge Woundwort)		
60 *Ajuga reptans* (Bugle)		
61 PRIMULA VERIS (Cowslip)		
62 *Plantago lanceolata* (Rib-wort Plantain)		
63 *Mercurialis perennis* (Dog's Mercury)		
64 *Ulmus montana* (Wych Elm)		
65 *Salix caprea* (Great Sallow)		
66 *Corylus avellana* (Hazel)		
67 *Orchis maculata* (Spotted Orchis)		
68 *Iris pseudacorus* (Yellow Iris)		
69 *Narcissus pseudo-narcissus* (Daffodil)		
70 *Galanthus nivalis* (Snow-drop)		
71 *Scilla nutans* (Blue-bell)		

INSECTS.

72 *Melolontha vulgaris* (Cock-Chafer or May-bug)	
73 *Rhizotrogus solstitialis* (Fern-Chafer)	
74 *Apis mellifica* (Honey-Bee)	
75 *Pieris brassicœ* (Large White Cabbage Butterfly)	
76 *Pieris rapœ* (Small White Cabbage-Butterfly)	
77 *Epinephile janira* (Meadow-brown butterfly)	
78 *Bibio marci* (St. Mark's-fly)	
79 *Trichocera hiemalis* (Winter Gnat)	

BIRDS.

(MIGRATION, SONG, NESTING, FIRST EGGS, &c. &c.)

80 *Strix aluco* (Brown Owl)	
81 *Muscicapa grisola* (Fly-catcher)	
82 *Turdus musicus* (Song Thrush)	
83 *Turdus pilaris* (Fieldfare)	
84 *Daulias luscinia* (Nightingale)	
85 *Saxicola œnanthe* (Wheat-ear)	
86 *Phylloscopus trochilus* (Willow Wren)	
87 *Phylloscopus collybita* (Chiff-chaff)	
88 *Alauda arvensis* (Sky-lark)	
89 *Fringilla cœlebs* (Chaffinch)	
90 *Corvus frugilegus* (Rook)	
91 *Cuculus canorus* (Cuckoo)	
92a *Hirundo rustica* (Swallow)	
92b *Hirundo urbica* (House Martin)	
93a *Cypselus apus* (Swift)	
93b *Caprimulgus europœus* (Goatsucker or Fern-Owl)	
94 *Columba turtur* (Turtle-dove)	
95 *Perdix cinerea* (Partridge)	
96 *Scolopax rusticola* (Wood-cock)	
97 *Crex pratensis* (Corncrake or Land-Rail)	
98 Frog Spawn. First appearance of.	

Signed *Observer.*

A Summary of these observations is published each year in the Quarterly Journal of the Meteorological Society.

The Scientific Enquirer.

Correspondence is invited on scientific subjects of all kinds. In all cases names and addresses should be given; but these will not be published if the writers prefer noms de plume. The Conductor will not be responsible for the opinions expressed by correspondents. All communications should be addressed to the Conductor of the "Scientific Roll," 7 Red Lion Court, Fleet Street, London, E.C.

Replies to questions should be numbered in accordance with the questions to which they refer. The contractions following the questions and answers indicate the class of notes to which they will ultimately be assigned, and the place where full references will be given to the details bearing upon them.

C. Climate.

The following questions by Sergt. John P. Finley are reprinted here with his permission, partly because they have a reference to clouds, and partly because it is hoped individuals will favour us with similar sets of questions on subjects they are interested in, and about which they desire to collect observations. The numbers in curved brackets are those given by the author, those which precede them are the numbers adopted for the "Scientific Roll" for the purpose of reference.

TORNADO STUDIES FOR 1882.

Without speaking too positively about the future, but unreservedly concerning the past, I can venture to say that the year before us will probably be a remarkable one in the chronology of its tornado season. Already and unusually early has the dreaded work commenced, and evidences are rife of unexampled fury coupled with those unmistakable signs which characterise the manifestations of the funnel-shaped cloud, never to be forgotten when once experienced.

Michigan was visited on the 6th day of April by remarkably violent tornadoes, especially the one which passed across the southern portion of the state, giving evidence of its wonderful power in Van Buren, Allegan, Kalamazoo, Barry, Eaton, Ingham, Livingston, and Oakland counties. This unfortunate and disastrous visitation upon the people of the Peninsula State was in part, but to a less degree, realised throughout portions of Iowa, Kansas, Missouri, and Illinois, on the same day and during the same afternoon.

Within the extensive barometric trough which consummated its energy on that fatal day, whose major axis extended southwestward from the Upper Lake region to northern Texas, and its minor axis from the Mississippi and Ohio rivers northwestward to central Minnesota and southern Dakota, there appeared three points of local atmospheric intensity, viz., central Kansas, northeastern Missouri, and the Lower Peninsula of Michigan. At the places here indicated the violence of atmospheric changes resulted in the formation of tornadoes.

The work of investigation in Michigan has to a certain extent been completed, at least so far so that it has been possible for me to accomplish the removal of my headquarters to Kansas city, Mo., where, under special instructions from the Chief Signal Officer, I shall prosecute the work of investigation in the Lower Missouri Valley.

This region of country embraces the states of Kansas, Nebraska, Missouri and Iowa, and can literally be termed the battle ground of tornadoes. It is here that this class of violent wind storms occurs with the greatest frequency, the most unexampled violence, the most marked regularity, and with the most complete manifestation of their peculiar characteristics. Con-

tinuing my labours until the expiration of the tornado season, I shall, aside from the examination of any particular tornado, with a view to gain new and important truths, give special attention to the following important features of this class of violent wind storms; viz., more definite information concerning the conditions precedent and favourable to the formation of tornadoes in general; the phenomena and laws of cloud development; the velocity and power of centripetal currents within the cloud vortex; additional statistics respecting the tornadoes of former years; the arrangement and perfection of an acceptable scheme whereby reliable warnings can be sent to certain communities in advance of the tornado, announcing that conditions are favourable to its formation; and lastly, to prepare and disseminate such information as will direct people how to act in defence of their lives, and to a certain extent of their property, during the approach and passage of a tornado. In the accomplishment of these momentous results, or in bringing to light new points of value, I am desirous to enlist the active support of every intelligent person throughout the Lower Missouri Valley or elsewhere. There are not a few ways in which even the humblest can assist. If you cannot give any *facts* concerning a tornado of recent date, write me what you *know* about one or more whose dates of occurrence number many years past. In every description of the tornado conform as nearly as possible to the character of the questions propounded in the accompanying circulars. Perhaps you can send me some article or publication bearing upon the climatology or meteorology of your state, or some portion of it. Photographs, sketches or printed cuts of the effects of the violence of any particular tornado, no matter what date, would be very valuable, and thankfully received.

As it will probably be impossible (owing to press of other work) for me to visit and conduct a personal examination in the case of every tornado that may occur in the Lower Missouri Valley or in adjoining states during the year, I will deem it a great favour, and it will certainly be a matter of most valuable service, if some one in the vicinity of a tornado's path will kindly undertake to furnish me (at his earliest convenience after the tornado's occurrence) with a complete history of its entire track. In performing this task, be careful to state as accurately as possible the place of beginning. This location is not necessarily where the tornado cloud *first* descended to the *earth*, although it may be, but more truly and hence more accurately, it is that particular spot or portion of country over which (perhaps at a great height above the earth) the funnel-shaped cloud was *first* seen to *form*.

Upon determining the place of commencement, carefully ascertain all the preliminary conditions of atmospheric changes existing prior to the development of the tornado cloud. In conducting the examination along the track and on both sides of it, make use of the questions and remarks contained in the respective circulars, according as one or the other is required. In determining the exact locality of final disappearance, exercise no inconsiderable vigilance, for you may most easily be deceived. It is a characteristic feature of the tornado cloud to rise suddenly from the earth, and, continuing its northeastward course in the lower regions of the atmosphere, again reach *terra firma* after an interval of several miles. You may find a number of these gaps along the tornado track you are examining, but do not mistake them for points of termination; rather look upon their existence as indubitable evidences of tornado (latent) activity, a sign of reappearance rather than disappearance. If these gaps occur in consecutive order as to time and place, pursuing, when taken together, a northeastward trend, and the difference in time of disappearance and reappearance at each interval, accounting for the passage of that interval, there can be no doubt of their forming disconnected parts of one and the same tornado track. The invariable accompaniment of the tornado, the hailstorm, *precedes* the first appearance of its terrible companion and *succeeds* its final disappearance. This characteristic should be carefully watched for and any peculiarity minutely recorded. If any in the prosecution of this particular work should need a quantity of circulars, the same will be mailed to them immediately, upon my receiving word as to how many of each kind they desire.

In the fulfilment of my mission I have no pet theories to advance or support, neither have I the time to speculate much or discuss the respective merits of uncertain or untenable positions; but I am prepared for the reception of *facts*, without measure. With regard to *suggestions*, I shall be a most willing recipient, and I trust that no one, feeling a desire in this direction, will hesitate to communicate with me at his earliest convenience. This is emphatically a public enterprise, and not the effort or exclusive pride of an individual.

It is absolutely necessary and most invaluable, when a variety of people are called upon to contribute in aid of a work like this, that they should know precisely *what* information is most desired.

With a view to cultivate familiarity respecting the character of the data required, I append herewith the following list of questions and remarks: Circular No. I contains a list of inquiries which are to be referred in all cases to persons who, on the day of the storm, were situated *without* the tornado's path (to the N. or S. of it), on its immediate edge, or from one to ten miles distant. In brief, this is a circular for *outsiders* only.

Circular No. II contains a list of inquiries which are to be referred in all cases to persons situated *within* the tornado's path. In brief, this is a circular for *insiders* only.

Circular No. III contains a list of inquiries which are to be referred in all cases to persons situated *without* the tornado's path (to the N. or S. of it), from 10 to 100 miles. Its scope is more general, and seeks for information concerning surrounding atmospheric conditions.

The information called for in each circular is in the main entirely distinct, but nevertheless equally important in conducting a careful analysis of the phenomena of this class of violent wind storms. I urgently solicit replies, on every hand and from every quarter, concerning the matter hereinafter set forth :

CIRCULAR NO. I.—QUESTIONS AND REMARKS.

8. (1.) How far and in what direction are you situated from the centre of the path of destruction? (C. 1.)

9. (2.) The time of day that the tornado cloud passed. (C. 2.)

10. (3.) The direction of the wind while the tornado cloud was approaching. (C. 3.)

11. (4.) The direction of the wind while the tornado cloud was passing. (C. 4.)

12. (5.) The direction of the wind after the tornado cloud passed. (C. 5.)

13. (6.) The direction of the wind during the fore part of the day and up to the time of the first threatening appearance in the heavens. (C. 6.)

14. (7.) The prevailing direction of the wind at this season of the year. (C. 7.)

15. (8.) Any hail, and did it fall before or after (how long) the tornado cloud passed? (C. 8.)

16. (9.) Were the hailstones large or small, of peculiar shape, and few or many in number? (C. 9.)

17. (10.) Did you examine the interior of any of the hailstones, and if so, how were they formed and what did they contain? (C. 10.)

18. (11.) If hail fell at intervals through the day, state the times of beginning and ending of each precipitation separately. (C. 11.)

19. (12.) Any rain, and did it fall before or after (how long) the tornado cloud passed? (C. 12.)

20. (13.) Any peculiarity in the size or shape of the raindrops, or in the quantity which fell? (C. 13.)

21. (14.) The direction of the wind at the time of the hail, and also at the time of the rain. (C. 14.)

22. (15.) If rain fell at intervals through the day, state the times of beginning and ending of each precipitation separately. (C. 15.)

23. (16.) What time of day did threatening appearances commence, in what portion of the horizon, and at what time were they the most decided? (C. 16.)

24. (17.) Describe the character and motion of the surrounding clouds before, during, and after the tornado cloud passed. (C. 17.)

25. (18.) Give the time of day at which the light or dark irregular clouds surrounding the tornado cloud were in the greatest confusion, and describe the scene. (C. 18.)

26. (19.) If you saw the tornado cloud, describe or sketch it, and note particularly any change in motion or the successive stages of development during the time of observation. (C. 19.)

27. (20.) Give the direction of the whirl of the tornado cloud, as against or with the hands of a watch. (C. 20.)

28. (21.) Give all the motions of the tornado cloud which you observed, or which you heard that others had witnessed; as for example: rising and falling, swaying from side to side, or whirling about a central axis, etc., etc. (C. 21.)

29. (22.) Thunder or lightning, in what portion of the horizon, at what time of the day and whether violent or otherwise. (C. 22.)

30. (23.) Was lightning seen in the funnel-shaped tornado cloud, or in the dark, heavy clouds surrounding it to the N. and W.? (C. 23.)

31. (24.) Was the day unusually warm and sultry? Give the maximum temperature if possible, and state the hour at which it was observed, together with the direction of the wind and the state of the sky existing at the time. (C. 24.)

32. (25.) Condition of the temperature after the tornado cloud passed. Did the air suddenly or gradually grow colder? (C. 25.)

33. (26.) What had been about the average daily temperature, together with the accompanying direction of the wind, for eight or ten days previous to the occurrence of the tornado? (C. 26.)

34. (27.) Give the direction of the course pursued by the tornado cloud along its path of destruction in your locality; as for example, N 70° E; E 30° N or E 20° S; etc., etc. (C. 27.)

35. (28.) Give the maximum and minimum width, in yards or rods, of the path of destruction in your vicinity; and state, if you can, whether, in examining that path, it was found that on the S. side of the centre the sweep of destruction was broader and more regular than on the N. side, or if any other difference existed between the two sides. (C. 28.)

36. (29.) If you, or any of your neighbours, have meteorological instruments, give the readings of the thermometer and barometer, direction of the wind and the hour of observation, for two days before, on the day of the storm, and for two days thereafter; viz. on the (C. 29.)

37. (30.) If you recall the occurrence. in times past, of any other tornado in your state, give year, month, day of month, hour of day, the direction of the course of the path of destruc-

tion as pursued by the tornado cloud, its length in miles, average width of destructive path in yards or rods, maximum width, minimum width, and, if possible, the hour of beginning and hour of disappearing of the tornado cloud. (C. 30.)

When I ask for direction of wind, I mean direction of motion of the surrounding air currents, independent of the course or motion of the tornado cloud.

When time of day is asked, give the same in hours and minutes, and state whether it is local or railroad time, and by what standard, viz., Chicago, Detroit, Columbus, St. Louis, etc., etc.

In giving your distance from the centre of the path of destruction, indicate the same in miles and parts of miles or rods, stating the amount in northing and easting, northing and westing, southing and easting, or southing and westing, estimated along section or township lines.

If not individually prepared to answer any or all of the above questions, please call to your aid such persons as may, in your judgment, be able to render you assistance.

If possible, try to represent the tornado cloud by a rough sketch, as also the dark and irregular clouds surrounding it.

In describing the path of destruction, be careful to note where the tornado cloud left the ground, where it again descended, the length of the interval and the topography of the earth at the points of ascension and descension.

Send any newspaper article concerning the storm which you may have or can obtain without inconvenience.

Give name and address of any one in your state who is in the habit of keeping a meteorological record.

If possible, try and secure the co-operation of some intelligent person, who, at the time of its occurrence, was situated either in the path of the tornado or on the outer edge of it, and who will be willing to furnish me a narrative of the result of his observations.

In all descriptions of the tornado's path, in giving any particular destruction in it, or in detailing your experience while the tornado cloud was passing, be careful to state on which side of the centre (to the N. or to the S. and how far) the damage occurred or you were situated while a witness of the scene.

CIRCULAR NO. II.—QUESTIONS AND REMARKS.

38. (1.) What day of the month and at what time of the day did the tornado cloud pass? Take great care in giving the exact time. Perhaps you watched your clock or noted the approach or passage of a railroad train. (C. 31.)

39. (2.) Give the position of your house with respect to the nearest post office, indicating the same in miles and parts of miles or rods; state the distance in northing and easting, northing and westing, southing and easting, and southing and westing, estimated along section and township lines. (C. 32.)

40. (3.) How far and in what direction is your house situated from the centre of the path of destruction? (C. 33.)

41. (4.) Give the direction and distance from your house to your various farm buildings, if possible drawing a plan of the same and indicating the points of the compass. This plan need only be a rough sketch. (C. 34.)

42. (5.) Give the dimensions of your buildings and state the character of each as to whether they are log, frame, stone, or brick, and weak or strong. (C. 35.)

43. (6.) In drawing a plan of your buildings, indicate the position of the tornado's path with respect to each of them and the direction in which the tornado cloud moved. (C. 36.)

44. (7.) State in detail and separately the damage to each building; what portion or portions were taken away or injured; how far and in what direction were they moved bodily; what portion of each was first struck by the wind, and how far and in what direction were the debris carried? Be very careful to give the exact position and peculiarities of structure of buildings which were not damaged although standing near those which were destroyed. (C. 37.)

45. (8.) In the damage or destruction of each or any building, state particularly how far and in what direction any portion of them was carried a considerable distance. (C. 38.)

46. (9.) If any object has been carried a long distance by the force of the wind, state where and what it came from; its dimensions; its shape; probable height to which transported in the air; whether driven into the ground or not, how far and into what kind of earth. (C. 39.)

47. (10.) State whether articles of clothing, fowls, or animals were carried into the air, to what height, to what horizontal distance, and in what direction. (C. 40.)

48. (11.) Give detailed destruction of furniture contained in the house and of farming implements in or about the barns. (C. 41.)

49. (12.) State the number, kind, and in what manner stock were killed or injured, and whether at the time of the storm they were in or without buildings. Also narrate any miraculous escapes of life. (C. 42.)

50. (13.) With respect to your family, give the whereabouts and condition of each person on the approach of the tornado, and also after the tornado cloud passed. Give age and sex of

each person, and particularise the character and extent of injuries to each. State very carefully the distance and direction in which any of the persons were carried, and also narrate any miraculous escapes of life. (C. 43.)

51. (14.) Be particular to note any evidence of the wind's extreme violence, as in the lifting of heavy objects; the twisting of trees or heavy pieces of timber; pulling up of fence posts; removing heavy stones, etc., etc. (C. 44.)

52. (15.) In describing the injury to any person, animal, or object, never fail to give the distance and direction of such person, animal or object from the centre of the path of destruction at the time the tornado cloud passed. (C. 45.)

53. (16.) With regard to destruction in orchards, among shade trees, and in forests, be particular to give the direction in which the trees lie; how they lie on the two sides with regard to each other and to the centre of the path of destruction; any special acts of violence in the twisting, uprooting, or breaking off of heavy timber; give circumference of large trees, height above ground where broken off, and dimensions of earth and roots where notably large trees were overthrown. (C. 46.)

54. (17.) In general, when giving the position of any person or thing with regard to the centre of the path of destruction, state the distance in feet or rods, and the direction, as N. or S. (C. 47.)

55. (18.) Give the maximum and minimum width, in yards or rods, of the path of destruction in your locality. (C. 48.)

56. (19.) How many funnel-shaped clouds did you see? Describe each, giving their relative sizes, shapes, and positions, and if possible a rough sketch of each. (C. 49.)

57. (20.) Did you hear a roaring noise on the approach of the storm, and if so, state the intensity, or any accompanying peculiarity. (C. 50.)

58. (21.) Did you notice any peculiarity with the manner in which small objects were suddenly removed from around about buildings as if sucked in by the advancing cloud? (C. 51.)

59. (22.) Did you notice any peculiarity in the falling of trees as the tornado cloud advanced upon them? Were they whipped about and bent to and fro as in a heavy wind, or were they drawn steadily inward toward the centre on both sides, as if by some mysterious but irresistible force? (C. 52.)

60. (23.) How many rods of fencing (stating kind) did you have blown down; in what direction were the N. and S. fences carried; what was the direction in which the E. and W. fences were carried? (C. 53.)

61. (24.) Give an estimate in money value of the loss to your property occasioned by the tornado, the number of acres of timber you had destroyed, and the number of fruit trees you had uprooted or broken off. (C. 54.)

62. (25.) Be particular to give the exact position, also the dimensions and probable strength and weight of small objects which were not moved from about large buildings, although the latter were entirely destroyed. (C. 55.)

63. (26.) Give the direction of the wind while the tornado cloud was approaching, while the tornado cloud was passing, and after the tornado cloud passed. (C. 56.)

64. (27.) The direction of the wind during the fore part of the day and up to the time of the first threatening appearance in the heavens. (C. 57.)

65. (28.) The prevailing direction of the wind at this season of the year. (C. 58.)

(29.) In asking for the direction of wind, I mean direction of motion from the surrounding air currents, independent of the course or motion of the tornado cloud.

66. (30.) Any hail, and did it fall before or after (how long) the tornado cloud passed? (C. 59.)

67. (31.) Were the hailstones large or small, of peculiar shape, and few or many in number? Give exact size and weight of the largest. (C. 60.)

68. (32.) On which side of the tornado's path (to the N. or to the S.) did the hailstones appear to fall in the greatest quantity? (C. 61.)

69. (33.) Did you examine the interior of any of the hailstones, and if so, how were they formed and what did they contain? (C. 62.)

70. (34.) If hail fell at intervals through the day, state the times of beginning and ending of each precipitation separately, together with the direction of the wind at each occurrence. (C. 63.)

71. (35.) Any rain, and did it fall before or after (how long) the tornado cloud passed? (C. 64.)

72. (36.) On which side of the tornado's path (to the N. or to the S.) was the rainfall the heaviest? (C. 65.)

73. (37.) Any peculiarity in the size or shape of the rain-drops, or in the quantity which fell? (C. 66.)

74. (38.) If rain fell at intervals through the day, state the times of beginning and ending of each precipitation separately, together with the direction of the wind at each occurrence. (C. 67.)

75. (39.) What time of day did threatening appearances commence, and in what portion of the horizon, and at what time, were they the most decided? (C. 68.)

76. (40.) Describe the character and motion of the surrounding clouds before, during, and after the tornado cloud passed. (C. 69.)

77. (41.) Give the general atmospheric conditions of temperature, wind direction, humidity, and clouds, for from ten to fifteen days previous to the occurrence of the tornado and from three to five days thereafter. (C. 70.)

78. (42.) Give the time of day at which the light or dark irregular clouds surrounding the tornado cloud were in the greatest confusion, and describe the scene. (C. 71.)

79. (43.) Describe any particular change or motion in the tornado cloud and the successive stages of development during the time of observation. (C. 72.)

80. (44.) Give the direction of the whirl of the tornado cloud, as against or with the hands of a watch. (C. 73.)

81. (45.) Describe minutely the manner in which objects were carried inward, upward, and about in the whirling vortex of the tornado cloud; how thrown outward and from what portion of the cloud. (C. 74.)

82. (46.) Describe the colour of the tornado cloud; its density; how and when changes in colour and density occur; the colour and density of the bottom of the cloud as compared with the top; the existence of light and peculiar fleecy clouds over and about the upper portion. (C. 75.)

83. (47.) Give the comparative size of top and bottom of tornado cloud; note particularly and describe minutely any change in form when the bottom or tail reached the surface of the ground. (C. 76.)

84. (48.) Did the tornado cloud remain in a vertical position as it travelled forward, or was the tail of it inclined; in what direction and how many degrees from the perpendicular? (C. 77.)

85. (49.) Give all the motions of the tornado cloud which you observed, or which you heard that others had witnessed; as for example, rising and falling, swaying from side to side, or whirling about a central axis, etc., etc. (C. 78.)

86. (50.) In examining the path of destruction, did you find any difference between the N. and S. sides of it? Which side was the widest; which the cleanest cut; which the most irregular and jagged along its outer edge; on which side were narrow paths of destruction cut inward toward the centre? (C. 79.)

87. (51.) Thunder or lightning, in what portion of the horizon, at what time of the day, and whether violent or otherwise. (C. 80.)

88. (52.) Was lightning or any other manifestation of electricity witnessed in the funnel-shaped tornado cloud as it approached or passed? If so, describe the appearance minutely. (C. 81.)

89. (53.) Was lightning seen in the dark heavy clouds surrounding the tornado cloud to the N. and W.? (C. 82.)

90. (54.) Was the day unusually warm and sultry? Give the maximum temperature if possible, and state the hour at which it was observed, together with the direction of the wind and the state of the sky existing at the time. (C. 83.)

91. (55.) What was the condition of the temperature after the tornado cloud passed? Did the air suddenly or gradually grow colder? Give the minimum temperature for that afternoon and evening, and during the night, with direction of the wind. (C. 84.)

92. (56.) What had been about the average daily temperature, also the maximum and minimum, together with the accompanying direction of the wind, for eight or ten days previous to the occurrence of the tornado and for three days succeeding its appearance? (C. 85.)

93. (57.) Give the direction, in degrees, of the course pursued by the tornado cloud along its path of destruction in your locality; as for example, N. 70° E.; E. 30° N., etc., etc. (C. 86.)

94. (58.) If you, or any of your neighbours, have meteorological instruments, give the readings of the thermometer and barometer, direction of the wind and the hour of observation, for two days before the day of the storm, and for two days thereafter, viz., on the (C. 87.)

When the time of day is asked, give the same in hours and minutes, and state whether it is local or railroad time, and by what standard, viz., Chicago, Detroit, Columbus, St. Louis, etc., etc.

If possible, try to represent the tornado cloud by a rough sketch, as also the dark and irregular clouds surrounding it.

95. (61.) In describing the path of destruction, be careful to note where the tornado cloud left the ground, where it again descended, the length of the interval; and the topography of the earth at the points of ascension and descension. Also state whether the hail and rain continued to fall after the tornado cloud rose from the earth and disappeared in the overhanging clouds. (C. 88.)

Send any newspaper article concerning the storm which you may have, or can obtain without inconvenience.

Give name and address of any one in your state who is in the habit of keeping a meteorological record, or who desires to keep one and would like instructions.

If possible, try and secure the co-operation of some intelligent person, who, at the time of the

occurrence, was situated either in the path of the tornado or on the outer edge of it, and who will be willing to furnish me a narrative of the result of his observations.

In all descriptions of the tornado's path, in giving any particular destruction in it, or in detailing your experience while the tornado cloud was passing, be careful to state on which side of the centre (to the N. or S. and how far) the damage occurred or you were situated while a witness of the scene.

96. (66.) Give an estimate of what you consider the progressive velocity of the tornado cloud; how many miles per hour. Give the data upon which you make the estimate, and why you believe your estimate to be reliable. (C. 89.)

97. (67.) What evidence can you give of the existence of upward and whirling currents of air within the central portion of the tornado cloud? (C. 90.)

98. (68.) Estimate the time in minutes or seconds during which the tornado cloud was committing the destruction at your buildings or in passing them at a safe distance. (C. 91.)

99. (69.) As the tornado cloud approached, from what direction came the wind you first experienced, whether against your body or against the building within which you were situated at the time? (C. 92.)

100. (70.) Did you notice any peculiar odour in the atmosphere during the passage of the tornado cloud, and what was it like? (C. 93.)

101. (71.) Do you know of any one who made observations on the presence of ozone in the atmosphere on the day of the storm? If so, send me his address or give the result of the observations. (C. 94.)

102. (72.) Do you know of any one who made observations with the galvanometer or compass concerning the deflection of the needle during the day of the storm, especially while the tornado cloud was passing a given point? If so, send me his address or give the result of the observations. (C. 95.)

103. (73.) Try and give an estimate of what you consider the wind's velocity within the central whirl of the tornado cloud, and also the data upon which you base this estimate. (C. 96.)

104. (74.) In the destruction of your buildings, did you notice anything in the disposition of the debris after the tornado cloud passed that would indicate the effect of an explosion; as, for example, the sides and the ends of a building being thrown outward and the roof carried off or let down upon the floor? (C. 97.)

105. (75.) In the passage of the tornado cloud over a pond, lake, or river, carefully describe every particular in the disturbance of the water; how high into the air any portion of it was carried; if any fish, shells, stones or the like were carried out and in what direction. Also state the exact position of the person or persons who witnessed the scene. (C. 98.)

106. (76.) Was mud, bits of leaves, straw, grass or the like thrown against your buildings? If so, state on what particular portion or portions, and whether apparently thrown thereon with great force. If thrown upon the bodies of persons or animals, carefully state the circumstances. (C. 99.)

107. (77.) Where trees were overturned and wrenched or twisted by the force of the wind, describe minutely how and in what direction the twist runs; that is, its direction, as with or against the hands of a watch. Perhaps you can compare it with the bit of an auger or indicate the same by a rough pencil sketch. Also state what portion or portions of the tree were twisted, and what the kind of timber. (C. 100.)

108. (78.) Observe carefully where the tornado cloud passed through forests, and state on which side of the tornado's path (to the N. or S.) the trees were broken off at a considerable height above the ground; the maximum and minimum height; general size of trees so affected; kind of timber, and whether broken square off or twisted. Try and illustrate the path through the timber by a pencil sketch showing the various directions of the prostrated trees. Indicate the points of compass. (C. 101.)

109. (79.) Did you notice any distinct peculiarity in the approaching or overhanging clouds from which the hail itself fell? Did the hailstones appear to drop from the funnel-shaped cloud, or from surrounding clouds? (C. 102.)

110. (80.) Sketches of clouds, of peculiar destructive effects, of hailstones, of anything that will illustrate any distinguishing feature of the storm's violence are very desirable. (C. 103.)

111. (81.) If you recall the occurrence, in times past, of any violent hailstorm in your state, give the place, year, month, day of month, hour of day, direction of the storm, maximum and minimum width of path in rods or miles, size and shape of hailstones, and a narration of the destructive effects. (C. 104.)

37. (82.) If you recall the occurrence, in times past, of any other tornado in your state, give year, month, day of month, hour of day, the direction of the course of the path of destruction as pursued by the tornado cloud, its length in miles, average width of destructive path in yards or rods, maximum width, minimum width, and, if possible, the hour of beginning and hour of disappearing of the tornado cloud. (C. 30.)

CIRCULAR NO. III.—QUESTIONS AND REMARKS.

112. (1.) Did you have a storm on this day? (C. 105.)

113. (2.) What was the nature of it? (C. 106.)

114. (3.) From what point, or points, of the compass did it approach? (C. 107.)

115. (4.) What was the hour of the day when it finally broke upon you? (C. 108.)

116. (5.) What was the highest velocity of the wind in miles per hour, and the direction from which it came? Approximate the velocity if you can do no better. (C. 109.)

117. (6.) What was the time of day when the maximum velocity occurred? (C. 110.)

118. (7.) Can you give the temperature at the time the highest wind velocity occurred? If not, say whether it was warm or cold. (C. 111.)

119. (8.) If a hail-storm, state whether the hailstones were large or small, of peculiar shape, and few or many in number. Give exact size and weight of some of the largest. (C. 112.)

120. (9.) What was the direction of the wind with the hail? (C. 113.)

121. (10.) Was there any peculiar condition of the clouds at the time of the hail? If any strange feature was noticed, give details. (C. 114.)

122. (11.) If hail fell at intervals through the day, state the times of beginning and ending of each precipitation separately, together with the direction of the wind at each occurrence. (C. 115.)

123. (12.) If any rain fell during the hail-storm, be careful to state whether it fell *before*, at the *time of*, or *after* the hail ceased. In case of the two extremes give the interval in minutes. (C. 116.)

124. (13.) If rain fell at intervals through the day, state the times of beginning and ending of each precipitation separately, together with the direction of the wind at each occurrence. (C. 117.)

125. (14.) What time of the day did the first threatening appearances commence, and in what portion of the heavens? (C. 118.)

126. (15.) How did the day open? (C. 119.)

127. (16.) What was the direction and force of the wind when you first noticed the weather in the early morning? Give the hour of observation. (C. 120.)

128. (17.) What was the condition of the sky when you made your first observation in the morning? Was it cloudy; three-fourths cloudy; one-half cloudy; one-fourth cloudy, or entirely clear? (C. 121.)

129. (18.) What was the direction, or directions, in which the clouds were moving at the time of your first observation? (C. 122.)

130. (19.) In the event of any storm whatever, give the direction and force of the wind while the storm was approaching, while the storm was passing, and after the storm passed. If a number of storms occurred on this day, give particulars of each, in accordance with the terms of questions Nos. 1 to 7, inclusive. (C. 123.)

131. (20.) What time of the day did it commence to cloud up, and in what quarter of the heavens? (C. 124.)

132. (21.) At what time, or times, of the day did you notice any freshening of the wind, and what was the direction at each occurrence? (C. 125.)

133. (22.) Describe the character of the clouds when the first threatening appearances began. (C. 126.)

134. (23.) Give the time of day, the quarter of the heavens, and the character of each formation, if there were frequent and sudden changes in the development or grouping of the clouds. (C. 127.)

135. (24.) How many days previous did you notice any indications of an approaching storm, and what were those indications? (C. 128.)

136. (25.) Did you observe that form of cloud commonly called "mare's tails" (cirrus); in what portion of the heavens and how many days previous? (C. 129.)

137. (26.) In what quarter of the heavens did the passing storm seem to be the heaviest? (C. 130.)

138. (27.) Could you distinguish any roaring noise with the storm; what was it like, and in what direction was it heard? (C. 131.)

139. (28.) Any damage to buildings, fences, or trees by the force of the wind or by lightning? If so, give the particulars. (C. 132.)

140. (29.) Did the clouds gradually thicken on this day, or was there a sudden and portentous banking-up of them in the W. during the afternoon? (C. 133.)

141. (30.) Did the clouds appear to gather near the earth and extend in irregular forms to great heights, or was there a heavy dark mass, with comparatively regular outlines, hanging low down in the W.? (C. 134.)

142. (31.) What time during the day, and in what portion of the heavens did you notice small light or dark clouds, if any, driven swiftly by the wind? Tell how they moved, from what direction or directions they came, and where they seemed to concentrate. (C. 135.)

143. (32.) In describing clouds, especially where they are peculiar or portentous in appear-

ance, aside from carefully indicating character of formation, give the most striking colours and state how they blended with each other. (C. 136.)

(33.) What is the prevailing direction of the wind at this season of the year, in your locality? (C. 7.)

144. (34.) In the event of the occurrence of any storm, state whether it passed your location by either the N. or S. point or directly overhead. (C. 137.)

145. (35.) Was the night of the day in question cold or frosty? Can you give its minimum temperature and the general direction of the wind? (C. 138.)

146. (36.) What time of the day did you notice any decided change in the temperature, and what was the extent of that change? (C. 139.)

147. (37.) Did thunder or lightning accompany the storm or storms on this day? If so, state in what quarter of the heavens it was the heaviest or most violent. (C. 140.)

(38.) In making a statement concerning any feature of the weather during the day, be careful to give the hour at which the condition referred to was observed.

(39.) Send me any newspaper article which you can obtain concerning the storm or storms.

(40.) Give name and address of any one in your state who is in the habit of keeping a meteorological record, or who desires to take observations and would like instructions.

148. (41.) What was the direction of the wind during the forepart of the day and up to the time of the first threatening appearance in the heavens? (C. 141.)

149. (42.) Give the general atmospheric conditions of temperature, wind direction, humidity and clouds, for from ten to fifteen days previous to this date, and from three to five days thereafter. (C. 142.)

150. (43.) Was the day unusually warm and sultry? Give the maximum temperature if possible, and state the hour at which it was observed, together with the direction of the wind and the state of the sky existing at the time. (C. 143.)

(44.) In any effort to indicate the *force* of the *wind*, use the following scale, employing the *words* or *figures* as you can best express the condition:

0	Calm.
1 to 2 miles per hour	Light wind.
3 to 5 miles per hour	Gentle wind.
6 to 14 miles per hour	Fresh wind.
15 to 24 miles per hour	Brisk wind.
25 to 39 miles per hour	High wind.
40 to 59 miles per hour	Gale.
60 to 79 miles per hour	Storm.
80 miles per hour and above	Hurricane.

(45.) Let me advise you to carefully observe and record the daily changes of the weather (if nothing more than miscellaneous phenomena) in your locality, if not throughout the year, at least from the 1st of April to the 1st of September. The Weather Bureau will probably need some *facts* from you each year, particularly such information as is herein set forth.

(46.) Can you not send me photographs, sketches, or printed cuts of the effects of the violence of any particular tornado, no matter what date? They will be very desirable. If you cannot furnish them, perhaps you know of some one who can. I am particularly anxious to obtain sketches of clouds, however rough and imperfect. If in any way you can roughly depict upon paper the unroofing, overturning, or crushing of a building, the destruction of an orchard, uprooted or twisted trees, or the falling or twisting of timber as the tornado cloud swept through the forest, it will be most valuable. Perhaps you know of some one who witnessed these scenes, or part of them, and who would be willing to illustrate them. Do not fail to send me something on this subject, if possible.

111. (47.) If you recall the occurrence in times past of any violent hail-storm in your state, give the place, year, month, day of month, hour of day, direction of the storm, maximum and minimum width of path in rods or miles, size and shape of hailstones, and a narration of the destructive effects. (C. 104.)

37. (48.) If you recall the occurrence, in times past, of any tornado in your state, give year, month, day of month, hour of day, the direction of the course of the path of destruction as pursued by the tornado cloud, its length in miles, average width of destructive path in yards or rods, maximum width, minimum width, and, if possible, the hour of beginning and hour of disappearing of the tornado cloud. (C. 30.)

ANNOUNCEMENTS.

Part III. of the "Scientific Roll" will be commenced, if life and health and support be granted to the Conductor, in 1883. In order that the bibliography may be as full as possible, authors and publishers are respectfully solicited to send copies of, or references to, all their publications dealing with the barometrical condition of the air.

As soon as 200 persons have expressed a wish to subscribe for any one of the subjects mentioned below, the publication of that section of the "Scientific Roll" will be forthwith commenced. The subscription price will be 7*s*. 6*d*. and 10*s*. for each volume, according as the residence of the subscriber is at home or abroad. Each volume will comprise from 400 to 500 pages; and each volume will, in most cases, contain two or more parts, each of which may be subscribed for separately. The extent of these parts will depend upon the amount of matter in hand, so that the subscription price for each cannot be fixed at present, but will be settled when the publication of each part is commenced. The following is a list of the principal subjects:—

Atmosphere, Water, Ocean, Rivers, Lakes, Springs, Glaciers, Land, Elevation and Subsidence of Land and Sea-Bottom, Denudation, Orography, Earthquakes, Volcanoes, Marshes, Minerals, Stratigraphy, Rocks, Plants generally and in classified groups; Animals generally; Protozoa, Actinozoa, Hydrozoa, Echinodermata, Crustacea, Scolecida, Annelida, Mollusca, Myriapoda, Arachnida, Rhynchota, Orthoptera, Diptera, Coleoptera, Lepidoptera, Neuroptera, Hymenoptera, Pisces, Amphibia, Reptilia, Aves, Mammalia, and Man.

Subscribers' names only are asked for now. The sending of these will not involve any pecuniary liability, but will simply be taken as implying that the senders take an interest in the work, and will probably undertake to subscribe when asked to do so.

AQUEOUS VAPOUR: NOTES.

1823.

Daniell, J. F. *Concluded from page* 219.

(*Page* 62) We must now provide some obstacle by which the course of the vapour may be retarded in its ascent; then may the condensation take place gradually and at different heights. The relative distances of these points of precipitation will depend upon the force of the vapour, and the greater or less facility with which it overcomes the mechanical obstruction. For the scale of temperature laid down, the following table would represent an adequate balance of evaporation and condensation with the appropriate degrees of elasticity between the points:

Height. Feet.	Sensible Temp.	Constituent Temp. of Vapour.	Elasticity.	State of Atmosphere.	Force of Evaporation.
0	80°	67.9°	.673	Clear.	327
5,000	64.4	[*]64.4	*.606	Cloudy.	467
10,000	48.4	19.0	.124	Clear.	
15,000	31.4	16.0	.112	do.	
20,000	12.8	[*]12.8	*.100	Cloudy.	80
25,000	−7.6	−20.7	.027	Clear.	
30,000	−30.7	[*]−30.7	*.020	Hazy.	

[*] are asterisks added in the 1845 Ed.

The last column gives the relative force of evaporation at the different points, supposing the total effect, if unopposed and sudden, to be 1000, and the same numbers will represent the comparative amount of precipitation at the several intervals of condensation, or the relative densities of the three clouds. In this manner the struggle between the elasticity of the stream [corrected to steam in 1845 Ed.] and the condensing power of the cold is divided and moderated, and the whole process becomes so gentle as quietly to restore the balance of force and temperature, provided the counteracting cause be not of a permanent nature. The moisture falling gradually back into the excess of heat below is converted into vapour of higher force, which pressing more upon the inferior strata proportionably raises their densities. From (*Page* 64) these considerations it would appear that, in any single column considered by itself, clouds of greater or less densities, and evaporation of greater or less force must be the consequence of a temperature decreasing in a more rapid progression than is due to the law of aqueous vapour. While the atmosphere is in the state represented in the last table, let us now contemplate the effects of a general reduction of sensible temperature upon the constituent temperature and the different points of precipitation. We will suppose the fall to take place gradually, and to amount to 18°. In the first place, the elastic force upon the surface will be diminished, but will approach the point of precipitation within 3°. A plane of condensation will be established between the surface and the height of 5000 feet. So likewise the vapour from 9000 to 14,000 feet will not be disturbed, but the second plane of condensation will descend from 18,500 feet to an intermediate position between that elevation and 14,000 feet. The shifting of these planes would not be sensible at the surface for the light precipitations which would

accompany their slow subsidence would be expended in equalising the temperature. We must next contemplate these various phenomena, hitherto considered as confined to a single column, in connection with adjacent sections. Let us take, as an illustration, the equatorial column of 80° in the state in which we have just considered it, and the adjoining one of 76·8°. The flow of the lateral currents may be determined by the following table:

	10° Lat.				0° Lat.			
Height. Feet.	Sensible Temp.	Const. Temp.	Elasticity.	State of Sky.	Sensible Temp.	Const. Temp.	Elasticity.	State of Sky.
0	76.8°	51.0°	.388	Clear.	80°	67.9°	.673	Clear.
5,000	61.1	48.0	.351	do.	64.4	[*]64.4	.606	do.
10,000	[*]44.9	45.0	.316	Cloudy.	48.4	19.0	.124	do.
15,000	27.7	12.0	.096	Clear.	31.4	16.0	.112	do.
20,000	9.3	9.3	.087	Cloudy.	12.8	12.8	.100	do.
25,000	−11.6	−32.0	.019	Hazy.	−7.6	−27.0	.027	do.
30,000	−35.0	−35.0	.016	do.	−30.7	−30.7	.020	do.

[The asterisks [*] are additions made in the 1845 Ed.]

(*Page* 66) In this table the first point of condensation above in the equatorial division is supposed to take place at the height of 5000 feet; while at latitude 10° it is fixed at 10,000 feet; and it will be seen that up to the former elevation the vapour of the first column is of much greater elasticity and density than that of the latter; it will consequently flow towards it with considerable force. No cloud will be formed, at the point of condensation, for the supply arising from the evaporation at the surface will be carried off in a lateral direction; or, if previously formed, would soon be dissipated by the same action. Nor would the transparency of latitude 10° be affected up to this height; for the current which it would receive would in constituent temperature still be below what its sensible heat would maintain. But above this line a dense cloud would be precipitated. A counter flow of small extent towards the equator will be established at 10,000 feet; and above this again the pressure will return to the first direction. The constituent temperature of the returning current being below the temperature of the elevation, the transparency of the equatorial column will be preserved throughout. These lateral currents are supposed to take place under the same mechanical retardation as the ascending vapour. Enough has been done to show generally that the necessary condition of transparency in any vertical section of an atmosphere of pure (*Page* 67) vapour, in which, from some extraneous cause the temperature diminishes faster than the natural progression, is that the quantity generated from the evaporation, necessarily accompanying such circumstances, should be carried off to adjoining regions. Let us now suppose that water is only partially diffused, and that the uncovered portions are absolutely dry. Vapour out of contact of water expands $\frac{1}{480}$ part of its volume for each 0° Fahr. If a current, therefore, were to pass over a dry space, heated to a degree higher than itself, the same changes in its constitution would take place in miniature as in dry atmosphere. The density would diminish, while its elasticity would (*Page* 68) remain the same upon the surface, and be increased at higher stations. The following table shows the effects of expansion upon vapour heated beyond the dew point:

Height. Feet.	Elasticity.	Const. Temp.	Sensible Temp.
0	1.0	80.0	90.0
5,000	.899	76.5	86.5
10,000	.808	73.0	83.0
15,000	.727	70.0	80.0
20,000	.653	67.0	77.0
25,000	.587	63.0	73.0
30,000	.527	60.0	70.0

Such modifications would necessarily ensue in the cases which have already been considered of the constituent temperature falling below the sensible heat; but, by comparing

this table with that on p. 54, it will be seen that the total effect at the greatest extreme does not exceed ·007 in. and it will be unnecessary in the general view we are taking of the subject to introduce a correction to such a small amount. In the case of vapour becoming heated in this manner out of contact with water, it may reach its point of deposition at a higher elevation without producing any sensible clouds; for although it would be instantly restored to the elastic form by the excess of heat in the inferior strata; and no accumulation could be formed for want of supply from the dry surface below—a slight haziness might be the result. Let us now imagine a stream of vapour (*Page* 69) of known density filtering its way laterally through the resisting obstacle which we have supposed, from one part of the sphere which is covered with water of a certain temperature to another which is perfectly dry, and of equal or superior temperature. As it arrives at the latter point it will diffuse itself rapidly over the dry space, and its elasticity being no longer confined by an incumbent atmosphere of like density will be reduced, and it will assume that force which its own diffusion will enable it to maintain. Or a stream of vapour, of high elasticity, flowing into a space where there already exists an atmosphere of inferior force, will be reduced in density to that of the general mean. In the next table [xxxii.] are represented two contiguous columns of vapour, the first incumbent upon water of the temperature of 70°, and the second upon dry land of the temperature of 80°. It is obvious that the former will flow into the latter, but will no longer be distinguished by its constituent temperature of 60°, but will be reduced to the standard of the second column of 32°. The elasticity of this column will rise with the difference of the first:

Gen. Temp.	Const. Temp.	Elasticity.	Gen. Temp.	Const. Temp.	Elasticity.
70°	60°	.524	80°	32°	.200

But the supporting surface may be neither water nor yet perfectly free from it, but we (*Page* 70) will imagine it to be earth differently imbued with moisture, and variously heated; then a partial supply, varying in quantity in different places, but of the same degree of density would take place, and clouds of more or less opacity would be formed at corresponding situations in the planes of deposition above. The following table will tend to illustrate these different positions:

Height. Feet.	General Temp.	Const. Temp.	Water 60.8° Atmos.	Water 60.8° Force of Evap.	Moist Earth 70° Atmos.	Moist Earth 70° Force of Evap.	Dry Earth 80° Atmos.	Dry Earth 80° Force of Evap.
0	60.8°	34°	Clear.	·368	Clear.	·507	Clear.	·786
5,000	44.6	31	do.	Density.	do.	Density.	do.	
10,000	27.9	28	Cloudy.	.368	Cloudy.	·092	Hazy.	
15,000	10.0	−6.4	Clear.		Clear.		Clear.	
20,000	−9.4	−9.4	Cloudy	.126	Hazy.	.021	do.	
25,000	−31.2	−31.2	Hazy.	.020	Clear.		do.	
30,000	−55.9	−55.9	Clear.		do.		do.	

(*Page* 71) The same general temperature is here supposed to prevail momentarily in every part of an atmosphere of equal force, resting upon a surface covered with water in one part, with moist earth in another, and dry in a third, and varying moreover in heat in the three situations. The first point of precipitation is placed at 10,000 feet. The water upon which the first part of the column rests is of the same degree of heat as the general temperature at the surface, the force of evaporation is 368, and as the supply is equal to the force, the density of the cloud is 368. The moist earth, upon which the second portion rests, is of the temperature of 70°, which makes the force of evaporation 507; but less steam being given off from the earth than from the water, the quantity of the precipitation is proportionally diminished. The dry surface which supports the third portion is heated to 80°, and yields no vapour; the evaporating force, which is equal to 786, is wholly unsupplied, and no cloud can therefore be maintained. The higher points are subject to the same modifica-

tions. The temperature of the evaporating surface regulates the quantity of water raised in vapour, the tension of the pre-existing atmosphere determines its elasticity. (*Page* 72) In the operations of the aqueous steam a power is developed fully adequate to produce the disturbances of temperature hypothetically proposed in the examination (*Page* 73) of the permanently elastic fluid. We may now investigate the compound qualities of a mixture of dry air and aqueous vapour, and their mutual relations so combined. The properties, which each possessed in its separate state, will be retained in this connection unchanged, and the two fluids will exercise no further action upon each other than a mechanical opposition when in motion. The particles of steam, in penetrating the interstices of the permanently elastic fluid, experience the same species of retardation as exists in their flowing through the pores of sand or cotton. When a state of equilibrium is attained, this mutual action ceases, and the particles of each press only upon those of their own kind. There are, therefore, two principal points of view under which such a mixture may be regarded—one in which the particles are in a state of equipoise amongst themselves, and the other where they are seeking an (*Page* 74) equilibrium by means of intestine motion. The first may be regarded as a homogeneous fluid. We will now inquire what will be the natural state of such an atmosphere surrounding a sphere of uniform temperature throughout. But we must first consider the effects of mixing known measures of the gases with vapour of different degrees of force. The first effect is increase of bulk under equal pressure in the permanently elastic fluid, not in proportion to the measure of vapour in it, but in proportion to its elasticity. Thus if we mix a cubic foot of dry air of the temperature of 212° and of the elasticity of 30 inches with as much steam as would rise in the space of a cubic foot of the same temperature, and consequently of the force of 30 inches, the mixture would occupy the space of two cubic feet. So if we mix a like measure of air of the temperature of 32° and of the elasticity of 30 inches with as much vapour as would form in the same space at the temperature of 32°, and consequently of the force (*Page* 75) of only ·2 inches, the bulk of the gas will only be increased ·00666 of a cubic foot. The second result is that the specific gravity of the gas is decreased, but not exactly in proportion to its expansion; for, while the vapour dilates its parts, it adds its own weight to the mixture. But this weight, though increasing with the elasticity, being, in all cases, less than that of an equal bulk of common air, decrease of density must follow. [See under 1793, Dalton, p. 101.] The diminution becomes greater with every increment of temperature. Let us imagine a homogeneous atmosphere of air of the temperature of 77° and 30 inches pressure; its specific gravity compared to air at 32° would be ·90626. Let us suppose this to be mixed with an atmosphere of vapour of the same temperature and ·91 inch force; the specific gravity of the mixture under equal pressure would be .89312; its total pressure would be 30·91 in., and its height would be increased from 28,775 feet to 30,260 feet. But as the temperature of a homogeneous atmosphere must fall on assuming that gradation of density which is essential to its natural state, the quantity of vapour must therefore (*Page* 76) suffer a proportionate reduction. The next table (xxxiv.) shows the small quantity of vapour which could exist with the atmosphere of air, supposing it saturated throughout.

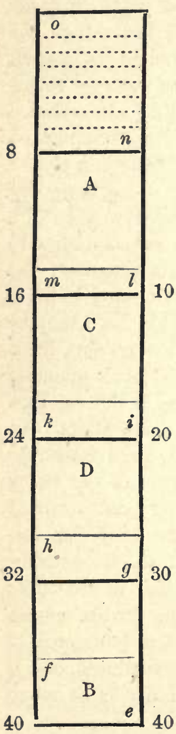
Height. Feet.	Temp.	Elasticity.
0	77.0°	.910
5,000	61.0	.542
10,000	45.0	.316
15,000	27.5	.171
20,000	9.3	.088
25,000	−11.0	.042
30,000	−35.0	.016

The average quantity [elasticity in 1845 Ed.], therefore, of vapour to this height could not exceed ·297 in. We must further consider that the altitude to which we have

followed our speculations has comprised but two-thirds of the total height of our atmosphere; the remaining third may, without any risk of error, be considered, from the lowness of its temperature, to be totally free from vapour. The mean pressure of the steam would thus be reduced to ·198 in.; and, supposing such a state of circumstances to be possible, the barometer would only rise from 30 in. to 30·198 in. in the atmosphere surrounding a sphere of the temperature of 70° by a change from absolute dryness to perfect moisture. Nor would such a state of saturation constitute by any (*Page* 77) means a natural condition of such an atmosphere as we are contemplating. Even if a general mixture could be effected, in the proportions which we have above imagined, the elasticity of the steam at the bottom of the column would be greater than the weight which the upper strata would confine; so that being urged upwards it would be condensed by the temperature of the air, which decreases faster than the progression due to the vapour, and the barometer would not rise to the height just stated. A state of complete mixture, in which all the particles would be at rest amongst themselves, cannot, therefore, exist in the natural ['compound'. in 1845 Ed.] atmosphere; and it can only, consequently, be regarded in the second point of view distinguished above, namely, as in a state of intestine motion. To place these particulars in a clearer light let us trace the progress of vapour just beginning to form in a perfectly dry atmosphere. For this purpose we will imagine the temperature of the sphere to be 77°. Let us now imagine water suddenly to overflow the surface, and evaporation will instantly commence. No atmosphere of vapour exists to impede its progress; the nascent steam will, therefore, merely assume the degree of tension necessary to overcome the vis inertiæ of the air which obstructs its motion. What this force may be we have not, perhaps, sufficient data to determine. We must, for the present, fix it arbitrarily and assume that at the temperature of 77° and pressure of 30 in., it amounts (*Page* 78) to ·200. The constituent heat of vapour of this elasticity is 32°, so that at the height of about 13,500 feet it would meet with its point of condensation. An aqueous atmosphere of such a degree of force being now established, fresh resistance to this amount is made to the progress of evaporation; and the elasticity of the rising steam must be doubled. Its constituent temperature is thus raised to 52°, and it cannot therefore pass the height of 7500 feet without decomposition. [The 1845 Ed. has 'deposition.'] The resistance upon the surface now amounts to ·601 in., to overcome which vapour at 65° must be emitted. The first point of precipitation in ascending from the surface would thus be fixed at about 3600 feet. We may now further remark that the diffusion of vapour does not cease at the height of 3500 feet [corrected to 13,500 in 1845 Ed.]; but the mechanical obstruction is proportionately reduced, and it is carried by successive stages to more lofty regions, where its tenuity is so much increased that it speedily eludes all observation.

With regard to the various points of condensation it is probable that no cloud would be formed in any of them. The process of evaporation would be so gentle under these circumstances that little above 6 grains of water would be raised per minute from the surface of a square foot; so that as the gradual precipitation of this quantity took place between the different stages it would instantly be redissolved by the excess of heat into which it would naturally incline to fall. The circulation thus becomes a process of equali-(*Page* 79) sation by which the temperature of the upper regions is raised, the heat which is abstracted below by evaporation is evolved by condensation, the pressure of the vapour is increased, and all the changes tend to that distribution of heat which we formerly contemplated as the natural state of an unmixed atmosphere of steam. The average quantity of vapour which would exist upon the hypothesis which we have just assumed, while the atmosphere maintained its proper progression of temperature, may be roughly approximated as follows: A stratum of the force of ·616 in. extends to the height of 3600 feet; another of the force of ·401 in. reaches 3900 feet farther; a third of only ·200 in. stretches almost as far as both the former together; making a total of

13,500 feet. The mean, therefore, to this point is nearly ·354 in. For the farther distance of 17,500 feet we cannot greatly err in taking ·064 in. as the mean pressure, making the average to the height of 31,000 feet ·209 in. One-third of the atmosphere beyond this being considered free from vapour reduces the mean to ·139 in. The following diagram may possibly tend to elucidate the effects of an unequal addition of matter or of unequal expansion in various parts of the same column of fluid. (*Page* 80.) Let A B represent the column whose height and weight we will call 40. Its four sections, A B C D are each equal to 10. Let us suppose an addition of matter to take place in B *ef* equal to 4; in D *gh* equal to 3; in C *ik* equal to 2; and in A *lm* equal to 1. The total increase of weight and pressure at the bottom will be 10, the same as if the total amount had been equally distributed throughout the mass or added at once to the top of the column on *no*. Again, if in the same column an unequal expansion were to take place in the four different sections, *ef*=4; *gh*=3; *ik*=2; and *lm*=1, the total increase of bulk *no* would be the same as if the expansion had everywhere been equal, and the weight at the base remaining the same, that of the sections would be altered from [0 added in 1845 Ed.] 10, 20, 30, 40, to 8, 16, 24, 32 and 40. In the case of the atmosphere which we are considering, both these changes are combined, the barometer rises at the surface of the sphere, and the weight of the several strata is still further changed. The following table exhibits the state of the barometer at equal altitudes before and after the admission of vapour in an atmosphere surrounding a sphere of the uniform heat of 77°, together with the temperature appropriate to the elevation and the dew point.



Height. Feet.	Temp.	Barometer. Atmosphere without vapour.	with vapour.	Dew Point.
0	76.8°	30.000	30.139	65°
5,000	61.1	25.214	25.348	52
10,000	44.9	21.193	21.318	32
15,000	27.7	17.812	17.928	9
20,000	9.3	14.970	15.079	0
25,000	−11.6	12.583	12.682	−35
30,000	−35.0	10.578	10.667	−35

Such, then, would be the new state of things from the admission of water to the surface of the sphere; a state, however, which, notwithstanding the equality of the superficial heat, could not be one of permanent rest. A perpetual struggle would ensue between the temperature due to the density of the air and the constituent temperature of the vapour, accompanied by perpetual evaporation below and simultaneous condensation above. No winds or lateral currents would be established, but an increasing (*Page* 82) circulation in a vertical direction. It will be observed that the total alteration of pressure is but small, even in the almost extreme case which has been selected, and the changes of density still less; it is in the unequal distribution and its consequent effects that we must seek for the principal influence of vapour in the mixed atmosphere. Changing now our hypothesis of the sphere of equal temperature for that of the sphere of unequal temperature, increasing from the poles to the equator, we will again assume that the barometer stands everywhere at the same height upon the surface, which height we will suppose to be 30 inches. The state of the vapour in the different columns of the mixed atmosphere is to be imagined to be in the same proportion as in the atmosphere which we have just been considering, that is to say, its constituent temperature at the surface of the sphere is to be within 11° of the temperature of the several zones. The arrangement is thus represented (Table opp. p. 82).

POLES.

Height. Feet.	Total Pressure.	Pressure of Vapour.	Sp. gr.	Temp.	Dew Point.
0	30.000 in.	.044	1.06666	0°	−11°
5,000	23.597		.86935	−18	
10,000	18.587		.70856	−37	
15,000	14.591		.57752	−58	
20,000	11.411		.47071	−82	
25,000	8.900		.38365	−109	
30,000	6.906		.31270	−140	

80°.

0	30.000	.047	1.06038	3°	−8°
5,000	23.652		.86542	−15	
10,000	18.630		.70637	−34	
15,000	14.642		.57654	−55	
20,000	11.484		.47057	−78	
25,000	8.965		.38408	−104	
30,000	6.978		.31352	−135	

70°.

0	30.000	.057	1.04685	9°	−2°
5,000	23.707	.033	.85684	−8	−17
10,000	18.724		.70140	−27	
15,000	14.775		.57407	−47	
20,000	11.617		.46991	−70	
25,000	9.102		.38463	−96	
30,000	7.100		.31483	−126	

60°.

0	30.000	.085	1.02607	19°	8°
5,000	23.793	.047	.84427	1	−8
10,000	18.893		.69405	−17	
15,000	14.969		.57061	−36	
20,000	11.827		.46904	−58	
25,000	9.314		.38558	−83	
30,000	7.302		.31699	−112	

50°.

0	30.000	.134	.99835	32°	21°
5,000	23.949	.079	.82563	14	6
10,000	19.106	.045	.68321	−3	−9
15,000	15.229		.56472	−22	
20,000	12.044		.46677	−43	
25,000	9.579		.38582	−67	
30,000	7.566		.31890	−95	

40°.

0	30.000	.237	.96358	48°	37°
5000	24.072	.139	.80230	31	22
10,000	19.338	.068	.66800	14	2
15,000	15.525	.037	.55629	− 4	−14
20,000	12.409		.46273	−24	
25,000	9.915		.38489	−47	
30,000	7.852		.32016	−62	

30°.

0	30.000	.375	.93463	61°	50°
5000	24.215	.221	.78245	44	35
10,000	19.531	.112	.65503	28	16
15,000	15.739	.046	.54855	10	− 8
20,000	12.673	.034	.45856	− 9	−17
25,000	10.162		.38327	−31	
30,000	8.135		.32035	−56	

Height. Feet.	Total Pressure.	Pressure of Vapour.	Sp. gr.	Temp.	Dew Point.
		20°.			
0	30.000 in.	.507	.91278	70°	59°
5000	24.279	.328	.76703	54	46
10,000	19.675	.162	.64489	38	26
15,000	15.898	.068	.54180	20	2
20,000	12.811	.046	.45500	1	− 8
25,000	10.342		.38166	−19	
30,000	8.313		.32010	−43	
		10°.			
0	30.000	.616	.89764	77°	65°
5000	24.319	.401	.75621	61	52
10,000	19.738	.200	.63762	45	32
15,000	16.012	.087	.53703	27	9
20,000	12.974	.064	.45147	9	0
25,000	10.467	.015	.38010	−11	−35
30,000	8.424		.31948	−35	
		Equator.			
0	30.000	.698	.89018	80°	69°
5000	24.342	.443	.75133	64	55
10,000	19.779	.229	.63436	48	36
15,000	16.060	.100	.53520	31	13
20,000	13.043	.071	.45068	12	3
25,000	10.521	.032	.37980	− 7	−16
30,000	8.483		.31980	−30	

(*Page* 83) The specific gravity and elasticity of the air is but very slightly affected by this intermixture of aqueous vapour. It will also be remarked that while the great aerial ocean is divided into two distinct strata flowing in opposite directions from N. to S. and from S. to N., the aqueous part, which is nearly confined to the lower current, presses in a contrary direction. The adjustment of these particulars remaining as now supposed, the compensating winds flow on and the balance remains undisturbed. The admixture of vapour which we have hitherto considered, has not yet affected the gradation of temperature resulting from the decreasing density of the atmosphere in its upper parts; the process of evaporation, however, which has been described must, in time, necessarily induce such an alteration. The stream [steam in 1845 Ed.], as it reaches its point of condensation, must give out its latent heat, and during its precipitation, combining with a fresh proportion, it again ascends and again evolves it in the middle regions. It may thus be considered as carrying caloric from the surface of the sphere to higher strata; and it is obvious how a considerable section of any one column may thus have its temperature equalised and fully saturated with aqueous particles. The currents (*Page* 84) thus become affected both by the expansive powers of the vapour and of the extricated heat; causes, the influence of which so applied must be partial and cannot reach the higher regions. The unequal action must produce a fall in the barometer. As upon the one hand this effect upon the barometer is produced by the augmentation of the aqueous vapour, so on the other, a rapid increase of the latter may be produced by a fall in the former. The mechanical resistance of the air must of course be increased by its motion in opposition. When this is stopped, as it soon is, by a trifling fall of the mercurial column, the vapour will rush forward with its whole force, retarded only by its filtration through the quiescent air; and, the temperature of the higher latitude being unable to support its elasticity, precipitation must follow. From the operation of these causes the temperature of the latitude is partially affected, the density of the air is still further reduced, and the aerial current is reversed. The course of the vapour is thus greatly accelerated, and abundant precipitation will follow. [An addition comes in here at page 114 of 1845 Ed.] When first formed in the higher elevations cloud would probably assume a light cirriform appearance; in lower regions

the precipitation would become denser, and the attraction of aggregation stronger; the (*Page* 85) mass would subside gently to a lower station, where the density of the air would oppose a greater resistance to its descent. Here, in a higher temperature, the cloud would again begin to be dissolved, and would assume a rounded and compact form; and thus the equalization of the temperature and the diffusion of the vapour would be carried on from several points at once. The different beds obey the impulse of the winds, and as they sail along enlarge the circumference of their action, till at length the natural equilibrium of the atmosphere can be no further curbed. The precipitation increases, the strata of the clouds inosculate, and the air no longer buoys up their load. It will be convenient here to subjoin a synoptic view of the force of the aerial currents, and the counter-pressure of the vapour in a mixed atmosphere surrounding a sphere unequally heated in the manner already set forth.

(*Page* 86) Table XXXVII. showing the force of the different currents in a mixed atmosphere of air and vapour between the poles and the equator. W = wind. V = vapour.

Lat. 90° and 80°. W.	V.	80° and 70°. W.	V.	70° and 60°. W.	V.
+.178	-.003	+.387	-.010	+.575	-.028
+.057		+.191		+.281	-.014
+.019		+.048		+.045	
-.023		-.063		-.093	
-.069		-.112		-.185	
-.078		-.152		-.240	
-.095		-.161		-.264	

60° and 50°. W.	V.	50° and 40°. W.	V.	40° and 30°. W.	V.
+.810	-.049	+1.034	-.103	+.854	-.138
+.375	-.032	+ .570	-.060	+.454	-.082
+.112		+ .217	-.023	+.215	-.044
-.084		- .035		+.031	-.009
-.149		- .239		-.131	
-.272		- .307		-.196	
-.321		- .322		-.291	

30° and 20°. W.	V.	20° and 10°. W.	V.	10° and 0°. W.	V.
+.648	-.132	+.447	-.109	+.208	-.082
+.392	-.107	+.282	-.073	+.118	-.042
+.165	-.050	+.159	-.038	+.053	-.029
+.038	-.022	+.036	-.019	+.008	-.013
-.024	-.012	-.068	-.018	-.045	-.007
-.128		-.074		-.054	
-.170		-.090		-.070	

(*Page* 87) The resistance which air opposes to the passage of vapour in motion may be regarded as twofold: first, in connection with the permanently elastic fluid at rest; and, secondly, with it in motion. With regard to the state of rest, the opposition with which vapour passes through air is in proportion to its density. De Saussure concluded from his experiments that a diminution in the density of one-third doubled the rate of evaporation. With regard to the state of motion, a breeze in opposition to the stream of vapour must retard its progress as much as one in the same direction favours it. Much obscurity envelopes this inquiry from the vagueness of the terms employed in denoting the velocity of the air. Dalton has determined that the rate of evaporation, in a perfect calm, being denoted by 120, that of a brisk wind is 154, and of a high wind 189. The retardation of opposing currents of the same respective forces may therefore be in proportion. Some important conclusions follow from these propositions, however wanting in precision. Thus, taking latitude 30°, the current which blows in the direction of (*Page* 88) lat. 40° may be deemed high, and retards the motion of the vapour towards lat. 20° accordingly. At the height of 10,000 feet the density of the air is reduced one-

third, and the velocity is consequently doubled; to which we must also add, that the opposing current, at the same elevation, declines in strength, whereby the force is again increased in the proportion of 189 to 154. More vapour, therefore, would probably pass at this elevation than at the surface, although its excess of elasticity is only .044 in. at the former station and .138 in. at the latter. Whenever a deep stratum of air has had its temperature and vapour equalized, it is easy to conceive that the aqueous atmosphere may travel in its upper part with considerable velocity in a course directly opposed to the wind at its lower. The approximation may be carried a little further, perhaps, as follows. The effect of a brisk wind in accelerating evaporation is equal to an increase of about three-tenths of the elasticity; that of a high wind, six-tenths. The retarding influence of the polar current, in its regular state, may therefore be apportioned to the different latitudes thus. From the poles to 80° = $\frac{1}{10}$ of the elasticity; to lat. 70°, $\frac{2}{10}$; lat. 60°, $\frac{4}{10}$; lat. 50°, $\frac{5}{10}$; lat. 40°, $\frac{6}{10}$; lat. 30°, $\frac{5}{10}$; lat. 20°, $\frac{3}{10}$; lat. 10°, $\frac{2}{10}$; and from lat. 10° to the equator, $\frac{1}{10}$. The following table then represents the efficient force of the vapour in a lateral direction calculated for the surface of the sphere and for the altitude of one-third the density.

(*Page* 89)

	Feet.	Height. Feet.	Balance of force.	Effects of wind and density.
90° and 80°	0		−.003	−.002
		10,000	−.001	−.002
80° „ 70°	0		−.010	−.008
		10,000	−.004	−.008
70° „ 60°	0		−.028	−.017
		10,000	−.008	−.017
60° „ 50°	0		−.049	−.025
		10,000	−.012	−.026
50° „ 40°	0		−.103	−.042
		10,000	−.023	−.043
40° „ 30°	0		−.138	−.069
		10,000	−.044	−.072
30° „ 20°	0		−.132	−.093
		10,000	−.050	−.090
20° „ 10°	0		−.109	−.088
		10,000	−.038	−.070
10° „ 0°	0		−.082	−.074
		10,000	−.029	−.058

(*Page* 90) These tables are simply rough tentative approximations. The last table will give some idea of the retardation of force in the vapour occasioned by the wind at the surface of the sphere; and also of the increase of velocity occasioned by dissimilar pressure in the upper regions. The permanency of the barometric pressure on the surface of the sphere is dependent upon the equal balance of the aerial currents, and its fluctuations are due to the destruction of the equipoise by unequal and local expansions and condensations. One of the chief causes of these latter, there can be no doubt, is the increase and decrease of the aqueous vapour counteracting the natural progression of temperature by the caloric evolved in its condensation; but there is another which must necessarily be powerful in this operation. It has hitherto been supposed, for the sake of simplifying the subject, that the source of heat has been in the sphere itself, and that all the regular changes of temperature have emanated from its surface. In a transparent state the sun's rays pass through the air without materially affecting it, and expend (*Page* 91) their energy upon the surface of the globe. But if the atmosphere becomes cloudy and opaque, the rays of heat emanating from an external source are in great part absorbed before they reach the surface, and an increase of temperature and elastic vapour must take place in the middle regions. To this we may also add the property which the clouds possess of preventing the radiation of heat from the surface beneath them, and the greater conducting power of damp than of dry air. Amongst the literally numberless modifications of circumstances to which an atmosphere of the nature we have been

considering is liable, there are yet two or three to which it will be necessary shortly to refer. The surface of the sphere has hitherto been chiefly considered as perfectly plain, and either thoroughly dry or everywhere covered with water. We will now contemplate it as covered with water to the extent of three-fourths of its superficies, uneven and intersected by eminences. This intermixture of land and water at once introduces inequalities of temperature of a different character from those that have been hitherto considered. They chiefly arise from the greater rapidity both of heating and cooling, on the dry surface, dependent upon the peculiar constitution of the watery element. As the processes by which their impressions are communicated to the superincumbent air are slow and gradual, they mostly affect the different columns in an equable manner, so that their influence upon the currents resolves itself into the cases which have been already proposed of total and regular expansion. With respect to the vapour the case is different. It is evident that the parts of the air which are immediately over the dry spaces will not remain free from its admixture, for the elasticity of the surrounding mediums will soon supply the vacuum. The rapidity of this equalization will depend upon the mechanical obstruction of the air being increased or diminished by an adverse or favourable wind. When once diffused over the land it would be more subject to condensation; and the amount of precipitation must be restored from the expanse of waters. The average quantity of vapour in the atmosphere decreases from below (*Page* 100) upwards, and from the equator to the poles. This is derivable from the (*Page* 101) laws of temperature, and is, moreover, amply confirmed by experiment. The condensation of elastic vapour into cloud raises the temperature of the air. This is confirmed by De Luc's observations. While reflecting on the sudden appearance of clouds, I observed a small bank of vapour towards the northward some 300 or 400 feet below me. I carefully watched it, and I then noticed that its volume was sensibly increasing without my being able to see from whence came the increase. Then I saw that instead of descending as it increased in size it became denser and higher. The wind blew it towards me. It at length reached me, and enveloped me so as to shut the view both of sky and plain. I bethought me at the moment of registering a thermometer which had been suspended in the air exposed to the sun, and which I had before seen at 4½ (42° F.). I presumed that the action of the sun being intercepted by the cloud, it would sink, but I was surprised to see it at 5½ (45° F.). The cloud, which was obliquely rising towards the south, soon passed the place where I was, and the sun re-appeared, but nevertheless the thermometer again sank (III. p. 251).

(*Page* 104) The western coasts of the extra-tropical continents have a much higher mean temperature than the eastern coasts. This difference is extremely striking between (*Page* 105) the western coasts of North America and the opposite eastern coast of Asia. It is explained by the heat evolved in the condensation of vapour swept from the surface of the ocean by the western winds. This general current, in its passage over the land, deposits more and more of its aqueous particles, and by the time that it arrives upon the eastern coasts it is extremely dry; as it moves onwards it bears before it the humid atmosphere of the intermediate seas, and arrives upon the opposite shores in a state of saturation. Great part of the vapour is there at once precipitated, and the temperature of the climate raised by the evolution of its latent heat.

(*Page* 107) Rain seldom occurs in the constant trade wind, and constantly in the adjoining latitudes. Between the tropics the elasticity of the vapour reaches its maximum amount; and within these limits only, rises to any extent into the upper current of the atmosphere. Its own force, therefore, is assisted by the equatorial wind, and it flows to the north and south as fast as it rises within the zone. No accumulation can therefore be formed, and the temperature being remarkably steady precipitation can but seldom occur. The continental parts of the same regions being liable to greater vicissitudes of heat, are subject to rainy seasons, which are periodical, like the monsoons of the same climates, and are governed as they are by the progress of the sun in declination. The

condensation while it lasts is in proportion to the density of the vapour, and is violent beyond anything that is known in temperate climates. The alternate seasons of fine weather are distinguished by cloudless skies and perfect serenity. The extra-tropical (*Page* 108) latitudes, on the contrary, beyond the bounds of the trade winds are at all times subject to great precipitations. The vapour in its course is subjected to a rapidly decreasing temperature, and the condensation is fed by a constant supply. Between the tropics the fluctuations of the barometer do not much exceed ¼ inch, while beyond this space they reach to 3 inches. Variations of temperature alone do not affect the mercurial column; and it is in the aqueous condensation we shall probably find the cause of barometrical changes. The vapour passing north and south from the equatorial parts and reaching the extra-tropical regions is precipitated. The effect of this precipitation must be to destroy the progression of temperature in the vertical columns by equalizing the heat of the strata exposed to its influence. But as the process is carried (*Page* 109) on chiefly in the lower current and cannot from its very nature equally affect the column, the total weight will be reduced by the consequent irregular expansion. In the temperate climates the rains and the winds are variable. The rain must depend very much upon the changes of the wind, and the retardation or acceleration which they offer to the progress of the vapour. But another cause arises from the unequal supply which the process of evaporation receives from the irregular surface of the globe. This cannot be placed in a stronger light than by the following considerations. The Caspian Sea, which is placed in the centre of the largest continent of the world, receives the precipitations of an immense tract of the atmosphere by means of the rivers which flow into it, and drain the neighbouring countries. The whole of this supply is again returned by evaporation and its waters have no other means of escape. The lakes of North America, situated in nearly the same parallel of latitude and at the same altitude, receive the drains of a much less space; but annually roll an immense volume of water to the ocean. We are thus furnished with an hygrometer upon a large scale by which we may (*Page* 110) judge of the state of saturation of the two atmospheres. The difference can arise from no other cause than the proximity of the surrounding seas in the latter situation which furnish an inexhaustible source of vapour which is deficient in the other. It is for the same reason that less vapour is contained in the atmosphere above a continent than above the ocean, although more rain falls in the former situation than in the latter under the same latitudes owing to the greater vicissitudes of temperature. Much of the aqueous atmosphere which is formed from the great deeps is thus drawn off towards the continents, where a scarcity of water occasions an inadequate pressure of the vapour (*Page* 111). In the extra-tropical climates a fall in the barometer always precedes a period of rain, and indicates an acceleration or change of the aerial currents. As the proximate cause of the fall of the barometer is an accumulation of aqueous vapour, and a consequent unequal expansion of the atmospheric columns, it is obvious that this alone would increase the probability of a proportionate precipitation; but it is not the only reason of the effect. The fall of the barometer indicates a decrease of density in the aerial currents, and, consequently, a decrease of the resistance to the passage of the vapour. A constant stream will thus rush in with increasing force, augmenting by (*Page* 112) its condensation the cause of its velocity, till a current sets in from some other quarter and restores the equilibrium. Northerly winds almost invariably raise (*Page* 115) the barometer; while southerly winds as constantly depress it. The (*Page* 116) northerly current is the natural course of the air. Coming from the frozen arctic regions it speedily reduces the accumulation of vapour, stops the supply, and dissipates the concomitant heat, from which originated the depression; and if it flow with a velocity beyond its regular rate, causes a reduction of temperature below the due progression, and augments the total weight; the southerly wind on the contrary facilitates the passage of vapour which by its unremitting condensation unceasingly increases the cause of depression. The supply of vapour which occasions rain may be traced to two

sources. One is the evaporation of the latitude itself, where it is precipitated; and the other, the stream which is perpetually struggling to advance from the equatorial zone. These causes sometimes act conjointly and sometimes separately. Rain from the first is derived from sudden falls of temperature produced by cold currents or the changes of the seasons, and assumes chiefly the form of showers of greater or less continuance. The expenditure of vapour is but slowly supplied, and the precipitation occurs at intervals. Rain from this source is always accompanied by a declining temperature. When on the contrary, in consequence of diminished pressure, the tropical current reaches in succession the colder parallels, the supply continues in a perpetual flow, the temperature (*Page* 117) is raised, the depression of the barometer increases, and rain descends with little intermission. Many persons have supposed that the fluctuations of the barometer are owing to the greater or less weight of the aqueous particles contained in the atmosphere at one time than at another. If, however, our theory be correct, the difference of pressure between a perfectly dry atmosphere and one saturated with moisture cannot much exceed .15 inch; the difference of the seasons must therefore be even less than this amount. But small as it is, it may nevertheless be detected by the system of averages. The subject of atmospheric vapour has hitherto been less studied than its importance would seem to require. A few general conclusions based on three years' (*Page* 118) observations by myself and an experiment by Captain Sabine, will add weight to our synthetic deductions. The elasticity of the aqueous vapour does not decrease gradually as we ascend in the atmosphere in proportion to the gradual decrease of the temperature and density of the air; but the dew point remains stationary to great heights and then suddenly falls to a large amount. I have been able to confirm this by direct experiment. [An addition is made here in the 1845 edition at p. 161.] The first experiments I shall refer to are by Green, who ascended in a balloon from Portsea on September 6, 1821, taking two of my hygrometers. At about 9840 [9890 in 1845 edition, page 162] (*Page* 119) feet he found the dew point to be 64°, or the same as I saw it to be on the earth's surface. At 11,060 feet it had fallen to 32°, making a difference of 32° in little more than 1100 feet. Here, then, we have presumptive evidence of an immense bed of circumambient medium, unaffected by decrease of density or temperature till checked by its point of precipitation; and of an incumbent bed of not much more than one-third the density, regulated, no doubt, as the last, by its own point of deposition in loftier regions. Captain [Colonel in 1845 edition] Sabine established the same fact at Sierra Leone. The dew point at sea level was 70°; and it was the same at the same hour on the summit of the Sugar Loaf Mountain, 2520 feet above. At the Isle of Ascension the readings were at 17 feet above the sea, 30.165 in. barometer, 83° temperature of the air, and 68° dew point. On the summit of the mountain they were 27.95 inches, 70° temperature, and 66.5° dew point; so that in a height of 2220 feet the temperature of the (*Page* 120) air fell 13°, and the constituent temperature of the vapour 1.5°. At Trinidad the temperature of the air at the sea level was 82° and the dew point 77°; 1060 feet above they were both 76.5°, and precipitation was going on. At Jamaica by the seaside the temperature of the air was 80°, and the point of deposition 73°, while on the mountains at a height of 4080 feet they were both 68.5°. At a station not 500 feet higher, the point of deposition was found to be 49°, and the temperature of the air 65°. These results are against the chemical solution idea, and favour the theory of mechanical mixture. Sabine's experiments furnish also some evidence of that slight diminution of density in the upper parts of the beds of vapour which would arise from the decrease of their own pressure. At Jamaica the dew point fell about 4.5° in 4080 feet. I have calculated this diminution to be 3.5° for 5000 feet for an atmosphere of much less density.

(*Page* 122) The tension of vapour given off in the process of evaporation is determined, not by the temperature of the evaporating surface, but by the elasticity of the aqueous atmosphere already existing. I have often endeavoured by means of the

hygrometer to detect, within a limited circle, a difference in the elastic force of the vapour incumbent on different surfaces of various temperatures, but without success; the rising vapour was always of the same quality, whether from water, vegetation, or ploughed land, in sunshine or in shade. For the same reason the dew point is but little affected by the increase of daily temperature from morning to afternoon, or by its subsequent declension at night. But one of the most remarkable confirmations of the fact was ascertained by Sabine upon the coast of Africa. While the sea breeze was blowing upon that station the hygrometer denoted the dew point to be about 60°, but when the wind blew strong from the land it approached in its character to a harmattan; and the point of precipitation was not higher than 37.5°, the temperature of the air being 66°. Notwithstanding the heat of the evaporating surfaces in the interior of that continent (*Page* 123), the burning sands of its desert yield so little vapour that it becomes attenuated by its diffusion, and there can be little doubt that the aqueous vapour incumbent upon it, and which when wafted to the coast constitutes the true harmattan, is not of greater force than that which rests upon the polar seas; and that while the heat of the air sometimes approaches to 90°, the constituent temperature of the vapour is below 32°. The apparent permanency and stationary aspect of a cloud is often an optical deception arising from the solution of moisture on one side of a given point as it is precipitated on the other. No phenomenon is more common amongst mountains or upon hills by the seaside than clouds upon the summits which appear to be perfectly immovable, although a strong wind is blowing upon them at the time. That this should be the real state of the case is clearly impossible, as so attenuated a body as constitutes the substance of the clouds must obey the impulse of the air. The real fact is that the vapour which is wafted by the wind is precipitated by the cold contact of the mountain, and is urged forward in its course till borne beyond the influence which caused its condensation, it is again exhaled and disappears. Reasoning from analogy we may conclude that the process which thus proceeds under our eyes upon the summits of the hills likewise takes (*Page* 124) place on either side of the planes of precipitation in the heights of the atmosphere; the vapour is continually condensed, as continually redissolved in the act of precipitation, and the cloud appears to be unchanged and stationary. The quantity of vapour in the atmosphere [in temperate climates, 1845 edition] in the different seasons of the year (measured on the surface of the earth and near the level of the sea) follows the progress of the mean temperature. This result of observation might readily have been anticipated, for the rate of evaporation and the quantity which the air can support are both obviously dependent upon the same progression. But this connection is not discoverable in short periods, and the changes of diurnal temperature do not much affect the quantity of elastic vapour. The air at night generally reaches the point of deposition even at the surface of the sea, but in a very gradual manner; and at the same time the supply from evaporation ceases. The progress of the vapour in fine weather may often be very satisfactorily traced by means of the clouds. During the heat of the day it rises from the surface of the land and water, and reaches its point of condensation in greater or less quantities at different altitudes. Partial clouds are formed in different parallel planes, which always maintain their relative distances. The denser forms of the lower strata, as they float along with the wind, shew the greater abundance of the precipitation at the first point of deposition, while the feathery shapes and lighter texture of the upper attest a rarer atmosphere. These clouds do not increase beyond a certain (*Page* 125) point, but often remain stationary in quantity and figure for many hours; but as the heat declines they gradually melt away, till at length when the sun has sunk below the horizon the ether is unspotted and transparent. The stars shine through the night with undiminished lustre, and the sun rises in the morning in its brightest splendour. The clouds again begin to form, increase to a certain limit, and vanish with the evening shades. This gradation of changes which we often see repeated in our finest seasons, might at first appear to be contrary to our principles; and that precipitation should occur

with the increase of temperature, and disappear with its decline, would seem at first sight to be diametrically opposite to all our conclusions. But a little consideration will shew that these facts confirm our theory. The vapour rises and is condensed; but in its precipitation falls into a warmer air, where it again assumes the elastic form; and as the quantity of evaporation below is exactly equal to supply this process above, the cloud neither augments nor decreases. When the sun declines, the surface of the earth cools more rapidly than the air, evaporation decreases, but the dissolution of the cloud continues. The supply at length totally ceases and the concrete vapour melts completely away. The morning sun revives the exhalations of the earth, and the process of nimbification again commences and again undergoes the same series of changes. The fall of the temperature shifts a little the planes of deposition, but scarcely affects the total pressure (*Page* 126) of the vapour. The deposition of dew slightly diminishes the quantity, but the first touch of the sun's rays restores it to the " blue expanse." When, however, the natural equilibrium has been disturbed, when the temperature of the air has become equalized through various successive strata by the beds of vapour with which they are embued, the decline of the day will often determine precipitation, and will increase its amount if already established. The result of experiment has already shown that a greater amount of rain falls while the sun is below than while it is above the horizon. The pressure of the aqueous atmosphere separated from that of the aerial, generally exhibits opposite changes to the latter. [This passage is modified in the 1845 edition, page 167.] As the quantity of vapour increases it will mostly be found that the barometer falls, and it rises with the decrease. This observation does not apply to the averages of the different seasons, but to the daily fluctuations. This fact, so utterly irreconcilable to the hypothesis which ascribes the rise and fall to the weight of the aqueous vapour, confirms that which attributes them to the unequal expansion of balancing currents. The prime source of this expansion we have supposed to be the elastic vapour, and this experience confirms the theory. Great falls of the barometer are generally accompanied by a temperature above the mean for the season, and great rises by one below the same. This is a confirmation of the same nature as the last, and inseparably connected with it. It is by the evolution of heat that the vapour principally acts. The mean temperature which balances all irregularities must be the regular temperature of the climate, and, *cœteris paribus*, that at which it must be most disposed to regularity; variations on either side of this point must produce corresponding retardations and accelerations; and these, if not general through the mass, annihilate the equipoise. The conclusions come (*Page* 128) to may be briefly recapitulated thus. There are two distinct atmospheres, mechanically mixed, surrounding the earth, whose relations to heat are different and whose states of equilibrium, considering them as enveloping a sphere of unequal temperature, are incompatible with each other. The first is a permanently elastic fluid, expansible in an arithmetical progression by equal increments of heat, decreasing in density and temperature according to fixed ratios as it recedes from the surface, and (*Page* 129) whose equipoise under such circumstances would be maintained by a regular system of antagonistic currents. The second is an elastic fluid, condensable by cold with evolution of caloric, increasing in force in geometrical progression with equal augmentation of temperature; permeating the former and moving in its interstices as a spring of water flows through a sand rock. When in a state of motion this intestine filtration is retarded by the inertia of the gaseous medium, but in a state of rest the particles press only upon those of their own kind. The density and temperature of this fluid have a tendency likewise to decrease as its distance from the surface augments, but by a less rapid rate than that of the former. The equipoise would be maintained by the adaptation of the upper parts of the medium in which it moves to the progression of its temperature and by a current flowing from the hotter parts of the globe to the colder. Constant evaporation on the line of greatest heat and increasing precipitation at every other situation, would be the necessary accompaniment of this balance. Now

the conditions of these two states of equilibrium are essentially opposed to each other. The vapour or condensable elastic fluid is forced to ascend in a fluid whose heat decreases much more rapidly than its own natural rate; and it is therefore condensed and precipitated in the upper regions. Its latent caloric is evolved by the condensation and communicated to the air, and it thus tends to equalize the temperature of the medium in which it moves, and to constrain it to its own law. This process must evidently (*Page* 130) disturb the equilibrium of the permanently elastic fluid by interfering with that state of temperature and density which is essential to its maintenance. The system of currents is unequally affected by the unequal expansion, and the irregularity is extended by their influence, much beyond the sphere of the primary disturbance. The decrease of this elasticity above is accompanied by an extremely important reaction upon the body of vapour itself; being forced to accommodate itself to the circumstances of the medium in which it moves, its own law of density can only be maintained by a corresponding decrease of force below the point of condensation; so that the temperature of the air at the surface of the globe is far from the term of saturation, and the current of vapour, which moves from the hottest to the coldest points, penetrates from the equator to the poles, without producing that condensation in mass which would otherwise cloud the whole depth of the atmosphere with precipitating moisture. The clouds are thereby confined to parallel horizontal planes with intermediate clear spaces, and thus arranged are offered to the influence of the sun, which dissipates their accumulations and greatly extends the expansive power of the elastic vapour. The power of each fluid being in proportion to its elasticity, that of the vapour compared with the air can never at most exceed 1 : 30; so that the general character of the mixed atmosphere is derived from the latter, which, in its irresistible motion, must hurry the former along (*Page* 131) with it. The influence however of the vapour upon the air, though slower in its action, is sure in its effects; and the gradual and silent processes of evaporation and precipitation govern the boisterous powers of the winds. By the irresistible force of expansion mechanically applied they give rise to undulations in the elastic fluid; the returning waves dissipate the local influences, and the accumulated effect is annihilated, again to be reproduced. By an invisible but ever active agency the waters of the deep are raised into the air, whence their distribution follows as it were by measure and weight, in proportion to the beneficial effects which they are calculated to produce. By gradual, but almost insensible, expansions the equipoised currents of the atmosphere are disturbed, the stormy winds arise, and the waves of the sea are lifted up, and that stagnation of air and water is prevented which would be fatal to animal existence. But the force which operates is calculated and proportioned; the very agent which causes the disturbance bears with it its own check, and the storm as it vents its own force, is itself setting the bounds of its own fury. The complicated and beautiful contrivances by which the waters are collected "above the firmament" and are at the same time derived from the waters which are "below the firmament," are inferior to none of those adapta- (*Page* 132) tions of Infinite Wisdom which are perpetually striking the inquiring mind in the animal and vegetable kingdoms. Had it not been for this nice adjustment of conflicting elements, the clouds and concrete vapours of the sky would have reached from the surface of the earth to the remotest heavens, and the vivifying rays of the sun would never have been able to penetrate through the dense mists of perpetual precipitation. Nor can I here refrain from pointing out a confirmation which incidentally arises of the Mosaic account of the creation of the atmosphere. The question has been asked, How is it that light is said to have been created on the first day, and day and night to have succeeded each other, when the sun has been described as not having been produced till the fourth day? This is apparently a contradiction. But Moses records that God created on the first day the earth covered with waters, and did not till its second revolution upon its axis call the firmament into existence. Now one result of the previous inquiry has been that a sphere unequally heated and covered with water

must be enveloped in an atmosphere of steam, which would necessarily be turbid in its whole depth with precipitating moisture. The exposure of such a sphere to the orb of day would produce illumination upon it; that dispersed and equal light which now (*Page* 133) penetrates on a cloudy day, but the sun could not have been visible from its surface. On the second day the permanently elastic firmament [= air] was produced, and we have seen that the natural consequences of this mixture of gaseous matter and vapour must have been that the waters would begin to collect above the firmament and divide themselves from the waters which were below the firmament. ["Waters" here then is used in its most general sense, and in the case of those above the firmament may be equivalent to clouds, hail, snow, or other atmospheric condition of the aqueous element.] The clouds would thus be confined to plains [= planes] of precipitation, and exposed to the influence of the winds and still invisible sun. The gathering together of the waters, and the appearance of dry land, would present a greater heating surface and a less surface of evaporation, and the atmosphere during this revolution would let fall its excess of condensed moisture; and upon the fourth day it would appear probable, even to our short-sighted philosophy, that the sun would be enabled to dissipate the still remaining mists and burst forth with splendour. Granville Penn's 'Estimate of the Mineral and Mosaical Geologies' gave me the first hint upon the subject. I had, however, already unconsciously proved the necessity of the turbid state of the atmosphere previous to the creation of the firmament.

(*Page* 139) *Nec non et in conviviis mensisque nostris vasa quibus esculentum additur sudorem repositoriis linquentia* [*liquentia* in 1845 edition] *diras tempestates prænuntiant.* C. Plin. Nat. Hist., lib. xviii. This passage has thus been translated into English: "And to conclude and make an end of this discourse; whensoever you see at any feast the dishes and platters whereon your meat is served up to the board sweat or stand (*Page* 140) of a dew, and leaving that sweat which is resolved from them either upon dresser, cupboard, or table, be assured that it is a token of terrible tempests approaching." Philemon Holland, 1601. This indicates that the viands were colder than the place they were brought into. I was induced to make experiments upon the deposition (*Page* 141) of dew on cooled glasses and vessels of brass. The Academicians del Cimento (*Page* 142) had previously experimented in the same way as regards principle. They cooled conical glass vessels and regarded the frequency of the drops which fell from the downwardly-placed point as a measure of the humidity of the air. Le Roi measured the temperature at which dew was formed, and judged of the humidity of the air by the greater or less degree of depression necessary to produce precipitation. Dalton in 'Mem. Lit. and Phil. Soc. Manchester,' vol. v., also measured the dew point as indicated by cooled vessels. Wollaston's cryophorus gave me the hint for making my hygrometer. I found metal to be no better than glass, when the glass is black and (*Page* 149) viewed by a reflected light. This hygrometer is simple; its graduation is not arbitrary; and it is not liable to deterioration; in proper hands it cannot give erroneous results. The determinations are as strictly comparable one with another under all circumstances as those of the barometer or thermometer. When consulted with a view of predicting the greater or less probability of rain or other atmospheric changes, two things are to be principally attended to—the difference between the constituent temperature of the vapour and the temperature of the air; and the variation of the dew point. In general the chances of rain or other precipitation of moisture (*Page* 150) from the atmosphere may be regarded as in inverse proportion to the difference between the two thermometers; but in making this estimate regard must be had to the time of day at which the observation is made. In settled weather the dryness of the air increases with the diurnal heat and diminishes with its decline; for the constituent temperature of the vapour remains nearly stationary. Consequently a less difference in the morning or evening is equivalent to a greater in the middle of the day. But to render the observation most completely prospective regard must be had to the

movement of the dew point. As the elasticity of the vapour increases or declines so does the probability of the formation and continuation of rain. An increasing difference, therefore, between the temperature of the air and the difference of the point of condensation, accompanied by a fall of the latter, is a sure prognostication of fine weather; while diminished heat and a rising dew point infallibly portend a rainy season. In winter when the range of the thermometer during the day is small, the indication of the weather must be taken more from the actual rise and fall of the point of condensation than from the difference between it and the temperature of the air. It must be (*Page* 151) remembered that a state of saturation may exist and precipitation even take place in fine weather, and under a cloudless sky; but this is when the diurnal decline of the temperature of the air near the surface of the earth falls below an unfluctuating term of precipitation; and it is probable that at some period or other of the twenty-four hours this term is always passed. The radiation of the earth, in the absence of the sun, cools the stratum of air in contact with it; and a light precipitation takes place, of so little density as totally to escape the observation of the eye. At other times it becomes visible and assumes the appearance of mist or fog. Under such circumstances the hygrometer will sometimes exhibit a different kind of action. If it be brought from an atmosphere of a higher temperature into one of a lower degree, in which condensed aqueous particles are floating, the mist will begin to form at a temperature several degrees higher than that of the air. The heat emanating from the ball of the instrument dissolves the particles of water and forms an atmosphere around it of greater elasticity than the surrounding medium; so that when it is put in action the point of deposition is proportionately raised. This action does not at all interfere with the determination of the real force and quantity of vapour; for in all such cases the full saturation of the atmospheric temperature must take place, and consequently the temperature of the vapour must be coincident with that of the air. This kind of precipitation, which may often be detected by the hygrometer when it would otherwise escape notice, (*Page* 152) far from being indicative of rain, generally occurs in the most settled weather. It is analogous to the formation of dew and is dependent upon the same cause, the radiation of the earth which only takes place under an unclouded sky. A sudden change in the dew point is generally accompanied by a change of wind; but the former sometimes precedes the latter by a short interval; and the course of the aerial currents may be anticipated before it affects the direction of the weathercock, or even the passage of smoke. My own experience and the testimony of others assure me that the hygrometer when applied is more to be depended upon than any instrument which has yet been proposed. Even when its indications are contrary to those of the barometer, reliance may be placed upon them; but simultaneous observations of the two most usefully correct each other. The rise and fall of the mercurial column is, most probably, primarily dependent upon the state of the upper regions of the atmosphere with regard to heat and moisture. Local chemical [physical in 1845 edition] alterations of its density, thus partially brought about, are mechanically adjusted, and the barometer gives us notice of what is going on in inaccessible regions. A rise in the dew point, accompanied by a fall of the barometer, is an infallible indication that the whole mass of the atmosphere is becoming imbued with moisture, and a copious precipitation may be looked for. If the fall of the barometer take place at the same time that the point of precipitation is depressed, we may conclude that the expansion which occasions (*Page* 153) the former has arisen upon some distant point, and wind, not rain, will be the result. But when the air attains the point of precipitation with a high barometer, we may infer that it is a transitory and superficial effect, produced by a local depression of temperature. Thus does the hygrometer mark with infallible precision the comparative degrees of moisture and dryness in the atmosphere. But it is of wider application. By means of tables we can find with the utmost accuracy and ease the positive weight of aqueous vapour diffused through any given portion of space, and its force or

elasticity is measured by the column of mercury which it is capable of supporting; we discover at once the proportion of moisture in any space to the quantity which would be required to saturate it, or what has been called the true natural scale of the hygrometer; we can calculate with perfect ease the specific gravity of any mixture of air and aqueous vapour; and we can measure the force and quantity of evaporation. [He then gives data upon which the tables are formed, which strictly belong to the physical properties of aqueous vapour, not to climate; but a few remarks are given here.] By two simple (*Page* 161) observations and easy calculations we ascertain the following points of the utmost interest in meteorology:

Temp. of air, 70°.
Dew point, 55°.
Degree of dryness on thermometric scale, 15°.
Degree of moisture on hygrometric scale, 618.
Weight of vapour in a cubic foot, 5.175 grains.

(*Page* 162) The state of the weather assumed above would constitute fine weather; and one of two things, or a modification of both, must happen before any precipitation of water could take place—either the temperature of the air must fall below 55°, or the quantity of vapour must increase to 8.392 grains in the cubic foot, the maximum quantity which could exist at 70°; or the point of condensation may become intermediate by a corresponding rise and fall of the two. In the first case the precipitation would probably be only slight and transitory, such as mist or fog; in the second case it would assume the form of hard rain and storms; while in the third, some conjecture might be formed of its probable duration and quantity, according as one or other of its causes prevailed. The hygrometer may also be applied to indicate the force and quantity of evaporation. Dalton ascertained that the quantity of vapour evaporated in a given time bore an exact proportion to the force of vapour at the same temperature. The atmosphere obstructs its diffusion, which would otherwise be instantaneous as in vacuo, but this obstruction is overcome with a celerity proportioned to the force of the vapour. The retardation is caused by the *vis inertiæ* of the particles of air, and is similar to that which a stream of water meets with in descending among pebbles. In ascertaining this point at ordinary atmospheric temperatures regard must be had to the force of vapour already existing in the air. For instance, if water at 57° were the subject, the force of vapour at that temperature is $\frac{1}{60}$ of the force at 212°; and one might expect the force of evaporation to be $\frac{1}{60}$ also; but if it should happen that an aqueous vapour to that amount does already exist, the evaporation would be nothing at all. On the other hand, if the aqueous vapour were less than that, suppose half of it, then the effective force would be $\frac{1}{120}$th of that from boiling water; in short, the evaporative force must be universally equal to that of the temperature of the water diminished by that already existing in the atmosphere. But the air, by its mechanical action, has another influence upon the rate of evaporation. When calm and still it merely obstructs the process; but when in motion it increases its effect in direct proportion to its velocity by removing the vapour as it forms. Dalton fixes the extremes that are likely to occur in ordinary circumstances at 120 and 189 grains per minute from a vessel 6 in. in diameter at 212°.

(*Page* 164) The following table shews the force of vapour and the full evaporating force of every degree of temperature from 18° to 85°, expressed in grains of water that would be raised per minute from a vessel 6 in. in diameter, supposing there were no vapour already in the atmosphere:

T.	Force of vapour.	Evaporative force in grains.		
212°	30.000 in.	120	154	189
18	.131	.52	.67	.82
19	.135	.54	.69	.85
20	.140	.56	.71	.88
21	.146	.58	.73	.91
22	.152	.60	.77	.94

T.	Force of vapour.	Evaporative force in grains.		
23	.158	.62	.79	.97
24	.164	.65	.82	1.02
25	.170	.67	.86	1.05
26	.176	.70	.90	1.10
27	.182	.72	.93	1.13
28	.188	.74	.95	1.17
29	.194	.77	.99	1.21
30	.200	.80	1.03	1.26
31	.208	.83	1.07	1.30
32	.216	.86	1.11	1.35
33	.224	.90	1.14	1.39
34	.232	.92	1.18	1.45
35	.240	.95	1.22	1.49
36	.248	.98	1.26	1.54
37	.256	1.02	1.31	1.60
38	.264	1.05	1.35	1.65
39	.272	1.09	1.40	1.71
40	.280	1.13	1.45	1.78
41	.292	1.18	1.51	1.85
42	.304	1.22	1.57	1.92
43	.316	1.26	1.62	1.99
44	.328	1.31	1.68	2.06
45	.340	1.36	1.75	2.13
46	.352	1.40	1.80	2.20
47	.364	1.45	1.86	2.28
48	.376	1.50	1.92	2.36
49	.388	1.55	1.99	2.44
50	.400	1.60	2.06	2.51
51	.414	1.66	2.13	2.61
52	.428	1.71	2.20	2.69
53	.444	1.77	2.28	2.78
54	.460	1.83	2.35	2.88
55	.476	1.90	2.43	2.98
56	.492	1.96	2.52	3.08
57	.508	2.03	2.61	3.19
58	.526	2.10	2.70	3.30
59	.543	2.17	2.79	3.41
60	.560	2.24	2.88	3.52
61	.577	2.31	2.98	3.63
62	.594	2.39	3.07	3.76
63	.615	2.46	3.16	3.37 { 3.87 in 1845 Edition.
64	.636	2.54	3.27	3.99
65	.657	2.62	3.37	4.12
66	.678	2.70	3.47	4.24
67	.699	2.79	3.59	4.38
68	.722	2.88	3.70	4.53
69	.745	2.98	3.83	4.68
70	.770	3.08	3.96	4.84
71	.796	3.18	4.09	5.00
72	.822	3.29	4.23	5.17
73	.849	3.40	4.37	5.34
74	.877	3.52	4.52	5.53
75	.906	3.65	4.68	5.72
76	.936	3.76	4.83	5.91
77	.966	3.88	4.99	6.10
78	.997	4.00	5.14	6.29
79	1.028	4.16	5.35	6.54
80	1.060	4.28	5.50	6.73
81	1.093	4.40	5.66	6.91
82	1.127	4.56	5.86	7.17
83	1.162	4.68	6.07	7.46
84	1.198	4.80	6.28	7.75
85	1.235	4.92	6.49	8.01 { 8.04 in 1845 Edition.

(*Page* 165) The first column contains the degree of temperature; the second, the

corresponding force of vapour; the third the amount of evaporation per minute from a vessel of 6 in. in diameter in calm weather; the fourth is the amount in a moderate breeze; and the fifth, in a high wind. The use of the table is this. Let it be required to know the force of evaporation at the existing state of the atmosphere; find the point of condensation by the hygrometer; subtract the grains opposite that temperature, either in the third, fourth, or fifth column, according to the state of the wind, from the grains opposite to the temperature of the air in the same column, and the remainder will be the quantity evaporated in a minute from a vessel of 6 in. in diameter under the given circumstances. For example, let the point of condensation be 55°, the temperature of the air 70° with a moderate breeze. The number opposite to 55° in the fourth column is 2.43 and that opposite to 70° is 3.96; the difference 1.53 grain is the evaporation per minute. But it is perhaps simpler and more convenient in many cases to estimate the depth of the water evaporated in a day, and Dr. Young has shewn how this may be done from Dalton's data. It happens that the column of mercury equivalent to the elasticity of vapour expresses accurately enough the mean evaporation in twenty-four hours. Mr. Dalton's experiment gives 45 grains per minute from a disc of $3\frac{1}{4}$ inches. Now $45 \times 60 \times 24 = 64{,}800$ grains or 256.6 cubic inches, which would (*Page* 166) make a cylinder 30.9 in. in height on a base $3\frac{1}{4}$in. in diameter; and this differs only $\frac{1}{33}$ from the weight of the column of mercury. We may therefore assume that the mean daily evaporation is equal to the tabular number expressing the elasticity of the vapour, sometimes exceeding it or falling short of it about one-fourth; and we may readily allow for the effect of the moisture of the atmosphere by deducting the number corresponding to the temperature of deposition. Thus supposing the mean temperature of twenty-four hours to be 60° and that of the dew point 50°, the evaporation will be equal to $.560 - .400 = .16$ in. It is evident that these estimates can be but mere approximations; for till we can obtain some accurate measure of the velocity of the wind, they must be liable to great uncertainty. They are, however, as much to be relied upon as the registers of the evaporating gauge in common use, whose only proper application can be to furnish a rough estimate of the state of atmospheric saturation and the point of deposition. The notion that they afford the absolute measure of the quantity of vapour raised into the air is absurd, for the instrument can only give the amount of evaporation from the shallow body of water in the place where it has been fixed. The conditions which modify the process vary almost *ad infinitum.* They vary on the land and on the water; they vary in sunshine and in the shade; they vary as land is more or less clothed with vegetation, or as water is more or less deep. The evaporating gauge, so far from representing the circumstances of those bodies which yield (*Page* 167) the great body of water on the earth's surface, probably does not correspond in all essential particulars with a dozen puddles in the course of the year. The results of the hygrometer accommodate themselves more easily to the ever varying conditions of the problem, and from these we can infer the effect of each combination of circumstances, and the capacity of the air for moisture modified by the velocity of the winds. The expansion which vapour causes in air is not precisely similar to that occasioned (*Page* 177) by heat; for while it dilates its parts it adds its own weight to the mixture. Let it be required to know the specific gravity of air at 32° saturated with vapour compared with dry air at the same temperature. Call the latter 1.00000; the quantity of expansion will be .00720; which deducted from 1.00000 leaves .99280. Now, the weight of a cubic foot of air under the conditions above-named is 558.131 grains, and the weight of a cubic foot of vapour at 32° is 2.539 grains, which, the former being 1.00000, will be nearly .00455; and which, added to the .99280 before obtained, will give .99735 for the specific gravity sought. Upon this principle I have constructed the following table, by means of which the specific gravity of any mixture of atmospheric air and aqueous vapour from 0° to 90° may readily be found with sufficient precision. I have made air under a pressure of 30 in. of mercury and at the temperature of 32° the

standard of comparison. The first column gives 0° F.; the second, the quantity due to each degree of heat to be subtracted or added according as the temperature is above or below the standard; the third exhibits the expansion of volume occasioned by vapour of the respective degrees of elasticity appropriate to the several degrees of heat, and is always to be subtracted; the fourth is the correction to be applied for the weight of the vapour, and is constantly to be added; and the fifth is the correct specific gravity, supposing the air saturated with moisture at the given temperature.

0	+.06666	−.00226	+.00153	1.06593
1	+.06458	−.00237	+.00159	1.06381
2	+.06249	−.00247	+.00166	1.06168
3	+.06041	−.00257	+.00172	1.05956
4	+.05833	−.00267	+.00179	1.05745
5	+.05624	−.00277	+.00185	1.05532
6	+.05416	−.00287	+.00191	1.05320
7	+.05208	−.00297	+.00197	1.05108
8	+.04999	−.00307	+.00204	1.04896
9	+.04791	−.00317	+.00210	1.04684
10	+.04583	−.00327	+.00216	1.04472
11	+.04374	−.00343	+.00224	1.04255
12	+.04166	−.00357	+.00234	1.04043
13	+.03958	−.00370	+.00243	1.03831
14	+.03749	−.00384	+.00251	1.03616
15	+.03541	−.00397	+.00260	1.03404
16	+.03333	−.00410	+.00268	1.03191
17	+.03124	−.00423	+.00276	1.02977
18	+.02916	−.00437	+.00284	1.02763
19	+.02708	−.00450	+.00292	1.02550
20	+.02475	−.00467	+.00302	1.02310
21	+.02291	−.00487	+.00314	1.02118
22	+.02083	−.00507	+.00327	1.01903
23	+.01874	−.00527	+.00339	1.01686
24	+.01666	−.00547	+.00351	1.01470
25	+.01458	−.00567	+.00363	1.01254
26	+.01249	−.00587	+.00375	1.01037
27	+.01041	−.00607	+.00387	1.00821

(*Page* 179)

28	+.00833	−.00627	+.00399	1.00605
29	+.00624	−.00647	+.00411	1.00388
30	+.00416	−.00667	+.00423	1.00172
31	+.00208	−.00694	+.00439	0.99953
32	.0000	−.00717	+.00454	0.99737
33	−.00208	−.00747	+.00471	0.99516
34	−.00416	−.00773	+.00486	0.99297
35	−.00624	−.00800	+.00502	0.99078
36	−.00833	−.00827	+.00518	0.98858
37	−.01041	−.00854	+.00533	0.98638
38	−.01249	−.00880	+.00549	0.98420
39	−.01458	−.00907	+.00564	0.98199
40	−.01666	−.00934	+.00580	0.97980
41	−.01874	−.00974	+.00604	0.97756
42	−.02083	−.01014	+.00627	0.97530
43	−.02291	−.01054	+.00650	0.97305
44	−.02475	−.01094	+.00674	0.97105
45	−.02708	−.01134	+.00697	0.96855
46	−.02916	−.01174	+.00720	0.96630
47	−.03124	−.01214	+.00743	0.96405
48	−.03333	−.01254	+.00766	0.96179
49	−.03541	−.01294	+.00789	0.95954
50	−.03749	−.01334	+.00803	0.95720
51	−.03958	−.01380	+.00839	0.95501
52	−.04166	−.01426	+.00864	0.95272
53	−.04374	−.01480	+.00896	0.95042
54	−.04583	−.01534	+.00926	0.94809
55	−.04791	−.01586	+.00957	0.94580
56	−.04999	−.01640	+.00987	0.94348

57	—.05208	—.01694	+.01017	0.94115
58	—.05416	—.01754	+.01051	0.93881
59	—.05624	—.01810	+.01083	0.93649
(*Page* 180)				
60	—.05833	—.01867	+.01114	0.93414
61	—.06041	—.01923	+.01146	0.93182
62	—.06249	—.01980	+.01178	0.92949
63	—.06458	—.02050	+.01217	0.92709
64	—.06666	—.02120	+.01256	0.92470
65	—.06874	—.02190	+.01295	0.92231
66	—.07083	—.02260	+.01334	0.91991
67	—.07291	—.02330	+.01372	0.91751
68	—.07499	—.02407	+.01415	0.91509
69	—.07708	—.02484	+.01457	0.91265
70	—.07916	—.02567	+.01503	0.91020
71	—.08124	—.02654	+.01551	0.90773
72	—.08333	—.02740	+.01598	0.90525
73	—.08541	—.02830	+.01648	0.90277
74	—.08749	—.02923	+.01699	0.90027
75	—.08938	—.03020	+.01752	0.89794
76	—.09166	—.03120	+.01810	0.89524
77	—.09374	—.03220	+.01861	0.89267
78	—.09583	—.03323	+.01916	0.89010
79	—.09791	—.03427	+.01973	0.88755
80	—.09999	—.03533	+.02030	0.88498
81	—.10208	—.03643	+.02090	0.88239
82	—.10416	—.03756	+.02150	0.87978
83	—.10624	—.03873	+.02213	0.87716
84	—.10833	—.03993	+.02277	0.87451
85	—.11041	—.04116	+.02343	0.87186
86	—.11249	—.04243	+.02411	0.86919
87	—.11458	—.04373	+.02486	0.86655
88	—.11666	—.04503	+.02549	0.86380
89	—.11874	—.04633	+.02618	0.86111
90	—.12083	—.04766	+.02688	0.85839

(*Page* 181) To find the specific gravity of any mixture of air and aqueous vapour, proceed thus. Note the temperature and the point of condensation; if they coincide, that is to say, if the air be in a state of saturation, we shall find the specific gravity required in the fifth column opposite to the proper degree of heat in the first column. If the point of condensation be below the temperature we must look for the correction to be applied separately for the heat in the second column. The quantity to be subtracted for the vapour of the given degree must be sought for in the third column, and must be applied minus the quantity due to its weight which stands beside it in the fourth. For example, if we wish to know the specific gravity of a mixture of air and vapour of the temperature of 60°, and of which the dew point is 40°, we find in the second column opposite to 60° the number .05833, which deducted from 1.00000 leaves .94167. In the third column opposite to 40°, we have .00934, and beside it in the fourth .00580. Now, .00934 – .00580 = .00354; which subtracted from .94167 leaves .93813 as the number sought. It has been objected that time is occupied in making observations with my (*Page* 187) hygrometer; but then one good observation is worth a thousand approximations. I have not experienced any difficulty in making observations owing to the time required. Moreover, by the ordinary instruments time is occupied in making calculations, and these are uncertain. Bibl. Univ., April 1819, says: Saussure's hair (*Page* 190) hygrometer changes in its degree of sensitiveness, so that the hair has to be (*Page* 191) changed every two years. Humboldt says: Saussure's instrument is most sensitive to the smallest changes of dryness, while De Luc's is most exact in very moist air; Saussure's instrument is liable to derangement in very high wind. Old (*Page* 192) hygrometers, if not corrected, have a tendency to indicate too great dryness. Leslie says hygroscopic substances are slow to receive their impressions, and hence

(*Page* 193) cannot be precise. All appear to lose tone. Saussure's hygrometer requires (*Page* 194) excessive care in its formation; and it is difficult to make comparable instruments. Moreover, the relations of its indications to the actual quantity of (*Page* 195) vapour in the air has not been determined. It is to be added that errors may arise from the disturbing influence of heat, the heat of the body being sufficient; (*Page* 196) the adhesion of dust, etc., the choking of the pivot of the wheel, and possibly friction from the index. Saussure says, a perfect hygrometer should have a range suffi- (*Page* 198) cient to indicate the smallest difference of humidity and dryness; should be sufficiently prompt in action to vary with the state of the air; always read the same under the same conditions; be comparable with other hygrometers; be affected only by (*Page* 199) aqueous vapour; all the degrees of the scale equal. Hutton suggested the use of the dry and wet bulb thermometer for hygrometric purposes. Observations with it may furnish data for solving the problem; but abstruse calculations are necessary, and many delicate and unsettled corrections. Leslie's form multiplies the source of error (*Page* 200). The observation in its most simple form is by no means so easy to make accurately as appears at first sight. It is almost impossible to prevent radiant heat interfering with the result. The temperature of evaporation is no longer that constant quantity which it is supposed to be, if dependent only upon the temperature of air, and is liable to fluctuations with every change of place and every breath of wind. The density of the air must also be taken into account, and it is allowed that the cold produced by evaporation from the moist bulb must depend in some measure upon the height of the barometer. The formulæ, corrections, etc., differ according to the authority, Leslie, (*Page* 201) Anderson, Ivory and Gay-Lussac. [He then gives experiments shewing (*Page* 202) the high degree of sensitiveness and accuracy of his hygrometer. In his (*Page* 234) essay upon radiation of heat in the atmosphere, he has numerous observations bearing upon aqueous vapour, but he does not describe any of the results as being due to aqueous vapour. Those only are mentioned here in which aqueous vapour is referred to; the others will be given under Temperature.] Scoresby in his 'Journal,' p. 291, says:—In cloudy weather no freezing of the sea, I believe, ever occurs when the temperature is above 29°; but in clear calm weather the sea, in the interstices of the ice, generally freezes on the decline of the sun towards the meridian below the pole, though the temperature be 32° or higher. In the instance now alluded to, the freezing commenced when the temperature was 36°, being 7½° or 8° above the freezing point of sea water. Leslie found the effect on his differential thermometer to depend upon the (*Page* 235) clearness of the atmosphere. [He has many observations in which he notices the state of the sky, but he does not make any special reference to the influence of the aqueous vapour. These observations belong to Temperature at London.] The oppres- (*Page* 264) sive effect of close weather and sultry days may probably be accounted for from the obstruction of the insensible perspiration of the body, which is prevented from exhaling itself into the atmosphere, already surcharged with moisture; while unimpeded transpiration from the pores, when the air is more free from aqueous vapour, adds new energy to all the vital functions. The mean quantity of vapour follows exactly the (*Page* 269) changes of the mean monthly temperature, that is to say, the dew point rises and falls with the increase and decrease of the heat. [This is based on observations in London.] The force of radiation in May in London from the surface of the earth is (*Page* 277) 13°; in April it was 14°. The reduction of this effect implies a rather more (*Page* 279) clouded state of the atmosphere in May than in April. In July the increase of the mean temperature appears to be wholly derived from the night. This must be owing to the cooling power having been checked by a cloudy sky. In October, the (*Page* 282) remaining heat of the earth is preserved from a needless expenditure, and (*Page* 301) guarded from a dissipation by an increasing canopy of clouds. The curves (*Page* 302) of monthly mean temperature and of the dew point [for London] shew how closely the constituent temperature of the vapour follows the mean temperature of the

air. It is more speedily diminished by the fall of the latter than it is increased by its rise. Hence arises the contrast between the dryness of the spring and summer months and the dampness of the autumn and winter. The force of the vapour appears to be (*Page* 303) governed chiefly by the minima of temperature; and a line connecting together the points of greatest depression would not differ very essentially from the dew point. A rise in the line is generally accompanied by a fall in the barometric curve (*Page* 304). The variations of the aqueous atmosphere are greater for equal differences at the upper than at the lower part of the thermometric scale.

Scientific Union.

The rapid progress of science now going on is, in part, the result of the great increase in the number of workers. This is accompanied by a larger and larger host of scientific serials. The consequence is that the student finds an increasing difficulty in ascertaining what has been done, or is in process of being accomplished, not only in his own special line of study, but also, and more particularly, in such as do not immediately interest him. Every student finds, from time to time, that he has a desire for full information on subjects in these outlying sciences, for the purpose of throwing light upon his special studies. The state of literature is such that he is frequently daunted by the difficulties attending his research, or, if he perseveres, he finds a great deal of time unnecessarily wasted. The remedy for this is the focalisation of knowledge round a series of centres. The two main steps in the process are, first, collection, and, next, classification. It is with this ulterior object in view, that all persons interested in meteorology are earnestly asked to forward their names and addresses, particulars as to the work they have done in meteorological and other sciences, their present lines of study, ways in which help is desired, and any other items that may occur to them. These details will be classified, and, when the opportunity offers, selections from them will be published. The Conductor will exercise careful discretion in the selection, as also in the use he may make of the more private details. The first list will be published in November, 1883; but correspondents are requested to send in answers soon, in order to allow of ample time for their classification, and for their utilisation in private correspondence in the interests of correspondents.

In order to prevent any misconception, it may be stated that the Conductor's object is solely to promote scientific union, and is no way intended to be of a charitable nature in any pecuniary sense. If there is a sufficient response to these requests, the same line of proceeding will hereafter be suggested, from time to time, for the students in other branches of science.

Newspapers and scientific journals of all countries, willing to help in this matter, are asked to make the above requests known to their readers.

Address, Conductor, "Scientific Roll" office, 7 Red Lion Court, Fleet Street, London, E.C.

We are glad to find that some attention is being given to the subject of promoting greater unanimity of action amongst our local Scientific Societies; but up to the present time the interest manifested has not been equal to what the importance of the movement demands. In the course of the present session we hope the numerous committees of

the local societies will consider the matter, and do what they can to help. The report of the last Conference is given below; and it is followed by extracts from a paper which the author, Dr. Baker, has kindly allowed us to reprint, which enforce the great need there is for combined systematic study of a subject which has hitherto been strangely neglected. In early numbers of the "Scientific Roll," remarks will be offered upon the systematic observations and plans of operation which have been made or adopted by local societies.

CONFERENCE OF DELEGATES FROM SCIENTIFIC SOCIETIES,

Held Annually during the Meeting of the British Association.

Third Conference. SOUTHAMPTON. 25th August, 1882.

MINUTES.

Present:	*Society represented:*
W. WHITAKER, B.A., F.G.S. (*In the Chair.*)	Norwich Geological Society. East Kent Natural History Society.
PETER PRICE	Cardiff Naturalists' Society.
F. T. MOTT, F.R.G.S.	Leicester Literary and Philosophical Society.
ALFRED T. BRETT, M.D. / H. GEORGE FORDHAM, F.G.S.	Hertfordshire Natural History Society and Field Club.
Rev. Canon ROGERS, M.A.	Royal Cornwall Polytechnic Society.
D. CORSE GLEN, F.G.S.	Geological Society of Glasgow.
CHAS. P. HOBKIRK, F.L.S.	Yorkshire Naturalists' Union.
WM. CASH, F.G.S.	Yorkshire Geological and Polytechnic Society.
WILLIAM GRAY, M.R.I.A.	Belfast Naturalists' Field Club.
CHARLES PUMPHREY	Birmingham Natural History and Microscopical Society.
F. A. BATHER	Winchester College Natural History Society.
RAPHAEL MELDOLA, F.R.A.S., F.C.S. / JOHN SPILLER, F.C.S.	Epping Forest and County of Essex Naturalists' Field Club.
JOHN KIRSOP, F.S.A., Scot.	Natural History Society of Glasgow.
THOMAS LISTER	Barnsley Naturalists' Society.
G. J. SYMONS, F.R.S.	

The Minutes of the Conference held at York, 6th September, 1881, were taken as read, confirmed, and signed by the chairman.

Mr. Fordham read the following report of the committee appointed at the York Conference:—"Report of the committee, consisting of Sir Walter Elliot, Mr. G. J. Symons, Mr. W. Whitaker, Mr. John Hopkinson, and Mr. H. G. Fordham, appointed at the Conference of Delegates held at York, 6th September, 1881, (1) 'to take steps to have the Conference of Delegates recognised by the Council of the British Association'; and (2) 'to send out a circular to the various local scientific societies, pointing out the work undertaken by the committees of the British Association, and the valuable aid which may be given by these societies in that and other scientific work.'

"1. The General Committee of the British Association having referred to the Council 'to consider the number and position of delegates from scientific societies, and the regulations which should be adopted for governing their relations to the Association,' the committee have thought it better not to make the formal representation to the Council contemplated in their instructions. Some communications on the subject have, however, passed between individual members of the committee and the officers of the Association.

"The Council have appointed a committee to consider and report on the question referred to them by the General Committee, and this committee having recommended to the Council 'that they be empowered to confer with delegates representing the societies, to ascertain in what way the Association might be able to aid them in obtaining a better organization and a more effective direction of their efforts in the cause of science,' and the Council having adopted this recommendation, your committee was invited to send one or two representatives to confer with the committee of the Council on the subject. The meeting was held on March 28th, when Mr. Hopkinson and Mr. Fordham attended on behalf of your committee, and the position and objects of the annual Conference of Delegates were discussed at some length. The results of this discussion are embodied in the report presented by the Council to the General Committee on Wednesday.*

"2. The committee have prepared and issued the circular to local scientific societies, with a circular letter, drawing attention to the annual Conference, and to the rule of the British Association under which delegates may become members of the General Committee, asking for a discussion of the circular and enclosures, and giving information as to the Conference to be held at Southampton. With this letter they sent a printed copy of the minutes of the York Conference.

"The circular itself referred to the work of three committees of the British Association (those on underground waters, erratic blocks, and underground temperatures), and to investigations relating to the following subjects:—Rainfall, periodical natural phenomena, and the appearance of and damage done by injurious insects. The following papers were enclosed with it:—Mr. Symons' pamphlet on the 'Arrangements for the systematic observation and record of the rainfall of the British Isles,' a copy of the table of monthly rainfall in Hertfordshire, and the form, with lists of plants, insects, and birds recommended for observation, issued by the Meteorological Society. A selected list of periodical natural phenomena (prepared by Mr. Hopkinson) and a list of injurious insects (from Miss Ormerod's publications) were printed at the end of the circular.

"The special thanks of the committee are due to Mr. Symons, and to the Meteorological Society, for copies of the pamphlet on rainfall, and of the phenological form, and the committee have also to thank the editor of the 'Scientific Roll' for reprinting in his publication the minutes of the York Conference, and the papers issued by the committee. About 200 copies of the circular, with the other papers enclosed, have been sent out to local scientific societies. The committee regret that they have not received many replies to their circular letter; on the other hand, in some cases applications for copies of the papers have been received from societies whose existence was not known to the committee, and no doubt a certain amount of interest has been aroused, and some practical good has been achieved, by putting before a large number of local scientific workers a definite proposal for systematic scientific work. The amount received in 5*s.* subscriptions at the York Conference was £3 10*s.*, and £1 has been since received by the committee. The expenditure up to the York Conference for printing and postage was £2 10*s.*, and the expenditure since incurred in printing and issuing the circular and other papers has been £4 14*s.*, showing a deficiency of £2 14*s.* There will also be some small additional expense in convening the present Conference."

"* The recommendations of the Council, which were adopted, after some discussion, by the General Committee, were as follows:—'(1) The omission in the rules (General Committee, Class B Temporary Members, § 1) of the words "and the Secretary of such Society," which follow the words, "or, in his absence, a delegate representing him." (2) The appointment of a committee in order to draw up suggestions upon methods of more systematic observation and plans of operation for local societies, together with a more uniform mode of publication of the results of their work,' and also, 'that this committee should draw up a list of local societies which publish their proceedings.'"

The adoption of the report was moved by Mr. Mott, seconded by Mr. Price, and unanimously agreed to.

The change made by the General Committee of the British Association in the rule of the Association relating to the appointment of representatives of scientific societies on that committee, by which the representation is now limited to the president of a society, "or, in his absence, a delegate representing him," was discussed at some length. It was pointed out that the presence of the president of a society at a meeting of the Association, even if only for a single day, and without his taking any practical part in the business of the General Committee, prevented his society being represented by a delegate on the committee, and in order to obviate the inconvenience arising in this and other ways from the wording of the rule, and to place in the hands of societies the direct appointment of their representatives, it was moved by Mr. Price, seconded by Mr. Glen, and unanimously resolved, that steps should be taken to amend the rule, so that it should read, " A delegate appointed by any scientific society publishing transactions." It was left to Mr. Fordham to bring this proposal before the Council and General Committee at the earliest opportunity.

The chairman drew attention to the desirability of obtaining greater regularity and method, and a nearer approach to uniformity of plan, in the publications of societies having similar objects, and undertaking similar work.

After some discussion, Messrs. Meldola, Hopkinson, and Fordham were appointed a committee for making the arrangements for the next Conference, to be held during the Meeting of the British Association in 1883.

It was referred to the committee to obtain one or two papers on subjects of interest to local scientific societies to be brought before the next Conference, in order to insure a regular discussion of special questions, and several matters were suggested as being suitable for consideration by the Conference.

Votes of thanks to the committee and to the chairman closed the proceedings.

THE SYSTEMATIC STUDY OF CAUSES OF SICKNESS AND DEATHS.

BY HENRY B. BAKER, M.D., SECRETARY OF THE STATE BOARD OF HEALTH OF MICHIGAN.

[*Reprinted in part from the Annual Report of the Michigan State Board of Health for* 1881.]

The first and most constant need of the sanitarian is accurate knowledge respecting those most common of all occurrences—sickness and deaths from diseases which during years and series of years have afflicted mankind. If it seems strange that there is so great lack of knowledge on such common subjects, it must be remembered that sanitary science is one of the latest sciences, and that physicians, as such, have had no need to record or to note many of those classes of facts which form the foundation of sanitary science, though some have had occasion to contribute greatly thereto. The prevention of sickness has not been their work, and the collection of facts respecting vast numbers of cases of sickness or deaths involves labour and expense too great to be borne by individuals, unless the knowledge gained thereby is such as will advance the work in which they are engaged. It has not been apparent that sanitary science would greatly advance the art of healing or the science of therapeutics, for which other classes of facts are needed, and for which they have been diligently collected, in times past. Though it is possible that the science of therapeutics might be fostered and advanced

by governmental aid, there seems to be no especial need for such aid so long as it is for the pecuniary advantage of individuals to perfect their knowledge of therapeutics in order to lead in the practice or teaching of their profession. But with sanitary science the case is very different,—there never has been, and there is not now in this State, any class of persons having such an income from any public-health service by the individual citizen as will permit of any effort for the collection of those facts which are essential to the beginning of sanitary science. In the statement just made I do not forget that progress in sanitary science and improved health-service increases the incomes of individuals generally throughout the State; this is undoubtedly true, but it does so by lessening expenditures and by increasing the ability to labour in ordinary and extraordinary pursuits. It is plain, therefore, that we cannot expect much progress in sanitary science without some such associated effort as that afforded by governments —State, National, and local. The old saying that "what is everybody's business is nobody's business" is particularly applicable in this connection; for though it is readily granted by every one we meet that "health is wealth," that "public health is public wealth," that "an ounce of prevention is worth a pound of cure," and that measures for the promotion of health are of vital consequence to every person, yet, except the government aids, there is now no person who can get a living by labouring for the prevention of sickness.

HOW CAN A GOVERNMENT PROMOTE SANITARY SCIENCE?

The chief duty of a government is to do for the safety of a people whatever they are unable singly or by practicable voluntary associations to do for themselves. If, as is now known to be the case, people die or suffer in great numbers from lack of knowledge which only the government can collect and diffuse among them, evidently it is one of the highest duties of the government to collect and diffuse that knowledge. That hundreds of such deaths have occurred in this State in every year is now established by good evidence.

WHAT KNOWLEDGE IS NEEDED FOR THE PREVENTION OF DEATHS.

Manifestly the first requisite for the prevention of deaths is a knowledge of the causes of the deaths. This has long been recognized by intelligent legislators, and in most civilized countries "vital statistics" have for many years been regularly and systematically collected. The same is true in many of the States of this Union. The history of progress in public-health movements shows that sooner or later the facts thus collected usually lead to some organized work for the prevention of deaths; thus in England, Annual Reports by the Registrar General relative to vital statistics have been published since the year 1838, while Reports by the Medical Officer of the Privy Council date from the year 1858, showing that after the beginning of vital statistics in England, twenty years elapsed before a general Board of Health was established with the view of attempting to systematize the public-health work, and make it more effective. In this country, in Massachusetts, vital statistics have been collected since 1842, and in 1869 a State Board of Health was established for the prevention of those deaths which the vital statistics showed to be most numerous. During the twenty-seven years preceding the establishment of a State Board of Health in Massachusetts, the statistics of deaths and their causes had been collected, published, and studied by citizens of that State, and the evidence was conclusive that many deaths occurred from causes known to be preventable, and many more occurred from diseases believed to be preventable or avoidable. In Michigan, vital statistics have been collected since 1868, and the State Board of Health was organized in 1873,—following the first inquiry for facts more speedily than in the older countries, partly because the vital statistics of Michigan soon showed that in Michigan as in Massachusetts, there were many pre-

ventable or avoidable causes of sickness and death, and suggested a similar agency for communicating to the people the knowledge necessary to avoid or prevent deaths from such causes. It must not be understood that the vital statistics alone are sufficient to give this important knowledge. It is said that a single bone enabled Owen to construct or reproduce the skeleton and form of an extinct species of animals, and subsequent discoveries of fossil remains confirmed his hypothesis and heralded another of the grand triumphs of mind over the difficult problems with which thinking minds everywhere are engaged. But it was to Owen, the diligent student of anatomy, the close observer of the many ways in which organ is correlated with function, and function with function, the learned teacher of the fundamental laws of structure and of the history and philosophy of structural development—it was to the keen eye and mind of *such* a man, and not to the mere delver in the earth by whose spade the bone was brought to light, that the communicative fossil disclosed its secrets of the past, its vision of the perfect form that should be revealed.

Thus it is not to the mere *compiler of vital statistics* that there is given a comprehensive view of the relations which the various classes of deaths bear to the varying conditions of soil, climate, age, occupation, nationality, social custom, individual habit, and pecuniary circumstances, by which the people of a State are surrounded, and of the various means of prevention or avoidance, direct and indirect, by which it is possible to lessen the death-rate of a State, diminish its burden of sickness, crime, and poverty, prolong the lives of its inhabitants, and promote their comfort, welfare, and happiness.

The man or the body of men who, from its vital statistics, shall construct the public-health service of a State must bring to the task the knowledge which can be acquired only at the feet of the masters of the medical sciences, and in the every-day walks of the physician; the familiarity with the manifold forms and habits of minute organic bodies, both animal and vegetable, which only the biologist has attained; the command of the inorganic substances and forces of nature which is bestowed only in the laboratory of the chemist; the knowledge of the formation and relative position of rocks and soils and of the relations of these to drainage and water-supply which is the reward of the geologist; the knowledge of climate which is the heritage of the meteorologist; the knowledge of the principles of government and of the moral nature of man which characterizes the lawyer; the power of commanding the attention and addressing the conscience of the people which is the glory of the orator and the preacher,—these qualifications and *more* are requisite not only to that study of vital statistics which shall discover the preventable causes of deaths, and elaborate practicable means for their removal or control, but also to that successful adaptation of means to ends by which the people shall be led to adopt and enforce practicable measures for their own protection and safety.

USES OF VITAL STATISTICS.

To vital statistics we are indebted not only for evidence showing the necessity of effort for the prevention of deaths, but such statistics are needed for constant reference in studying methods by which the deaths may be prevented. Before we can act intelligently for the prevention of deaths from any given disease or cause, we need to know the time of year at which the danger is greatest, the ages at which a person is most in danger, to persons of which sex the danger is greatest, whether the danger is greater in one part of the State or country than in another, and many other facts. Vital statistics, accurately collected, compiled, and studied, for a period sufficiently long, will give us such information.

WHAT ARE "CONTRIBUTIONS TO SANITARY SCIENCE"?

It is, I think, just as important to "know a good thing when we see it" in public-health work as in any other affair; therefore it is well to bear in mind that popular books

and articles are not usually "contributions to science," that papers (such, for instance, as this one) read at public meetings are not usually "contributions to sanitary science," and that really valuable "contributions to science" are not commonly easy and pleasant reading, notwithstanding their high value in advancing existing knowledge. A science is built up by the accumulation of numerous facts, which, ultimately, are grouped so as to exhibit general truths. When an individual or a government collects numerous facts, and skilfully groups those facts so as to lead to new knowledge bearing upon the problems with which public-health work deals, that individual or that government makes an important contribution to sanitary science. However useful it is to have essays on public-health work in all its various departments, and however much good may be done because of the stimulus of such essays, which I consider essential to progress in sanitation, yet it must not be forgotten that the real solid basis of all such work must be laid in the patient, painstaking accumulation of facts (such as physicians are freely contributing), their classification, comparison, collation, provisional grouping, and final grouping so as to serve as bases of action. Thus the recognized basis of sanitary science is statistics—of deaths, of sickness, of meteorological and other surrounding conditions, though very much more than such statistics is needed for an effective public-health service.

USEFUL FACTS FROM THE VITAL STATISTICS OF MICHIGAN.

Facts illustrating the nature of some of the information gained by means of vital statistics already collected in this State, may be given: It has been learned, for instance, that in this State, during a long series of years, the danger from small-pox was not as great as the danger of death from whooping-cough, there being twice as many deaths from whooping-cough as from small-pox (though the proportion of children is greatest among those who die from whooping-cough). It has been learned that diseases of the lungs cause nearly one-fifth of all the deaths reported in this State, and that nearly one-half of all the deaths are attributed to diseases of the lungs, the bowels, and the brain; and it is found that a large proportion of the deaths from each of these three groups of diseases are reported to be caused by tubercular diseases, such as consumption of the lungs, consumption of the bowels, tubercular disease of the brain and coverings, etc., so that if, as now seems probable, sanitarians shall soon be able to class consumption among the preventable diseases, and to teach people how to prevent a considerable proportion of the deaths now charged thereto, it will be one of the grandest achievements of the century; for it will add more to the financial prosperity of the people than can be easily computed, hundreds of thousands of dollars annually now being lost to the people of this State by reason of sickness and deaths from consumption; and then the anguish of human hearts beyond any power of computation or expression!

The deaths reported from consumption in Michigan will average over 1,400 annually, and there is evidence that the number reported should be much increased in order to equal the deaths which actually occur; probably two thousand persons die in this State in every year from consumption. And yet compared with many other States Michigan is a very healthful State, and we are accustomed to regard these deaths as inevitable—indeed, as a rule, they seem to be when once consumption has been contracted; and up to this time no effort has been made to prevent the spread or occurrence of this disease. It may serve to awaken the enthusiasm sufficient to start some effort for its study and restriction, if we consider that consumption is now proved to be communicable from man to lower animals; that there is good evidence that the disease may be communicated from animals affected with it to man—as, for instance, to susceptible children by means of milk of a tuberculous cow, to any susceptible person by means of insufficiently cooked meat of a tuberculous animal; that there are hundreds of tubercular cows and other animals; and that consumption is probably spread among people in unventilated rooms by breathing air which has come from the lungs of persons

suffering from consumption. The evidence of this last proposition is twofold—because from statistical and other evidence some have been convinced of the truth of it, and lately experiments have shown that dogs will contract the disease if caused to breathe air in which tuberculous matter has been anatomized. Let us place these facts by the side of those others which the vital statistics give us—namely, that, counting all children and grown people in this State, at least twelve per cent. die from consumption—an average equal to every eighth person you meet in this State; and we may add that the death-rate is reported about double this among persons over fifty years of age; thus we begin to see abundant reason for tremendous effort to learn the whole truth, and then for another effort for the prevention of this great waste of human life, which is going on among us.

THE VALUE OF REPORTS OF SICKNESS.

Until recently sanitarians have been obliged to accept as their best guide in the study of the causes of sickness the facts reported concerning the number, time, and alleged causes of deaths; but evidently there is much sickness which does not result in death, but which, nevertheless, it is very desirable to prevent if possible, and there are many deaths having a remote cause in sickness or other conditions quite different from those immediately preceding the death, and likely to be reported as its cause; so that statistics concerning the sickness of a people are no less necessary than those concerning deaths. Weekly reports of sickness also serve to announce to a State Board of Health, outbreaks of communicable diseases, and thus enable the board to direct attention in various parts of the State where such diseases occur, to necessary measures for the restriction and extirpation of the disease. For such timely work by the State Board a system of prompt and regular reports of sickness is essential. Yet it is only for a few years that the attempt has been made to collect statistics of sickness; and at this time I know of no such systematic effort being made elsewhere for the collection of facts respecting sickness as that by the Michigan State Board of Health. This Board receives weekly reports of the sickness under the observation of many of the leading physicians in this State, about one hundred of whom in nearly as many different parts of the State promptly notify the Board of the outbreak of any communicable disease, and regularly report concerning the relative prevalence of cases of each of the prominent diseases under their observation. This makes it possible for the State Board of Health to send promptly to each locality, documents bearing upon the restriction of any particular disease which occurs, concerning the restriction of which the State Board has gained useful information; provided the State Board has the means to print and to distribute documents in that manner; and such distribution is desirable even if the document has been generally distributed before, because, during an outbreak of a disease, many will seek and gain information relating to that disease, who will not do so at other times. But aside from keeping the State Board constantly informed concerning the health or sickness of the people, the weekly reports of sickness have great value as contributions to our exact knowledge on the subject; because the facts thus reported can be systematically arranged, compiled, and joined with other facts similarly arranged respecting the surroundings of people at different ages and at different seasons of the year, and knowledge may thereby be gained which will eventually enable the board to tell the people the conditions under which sickness from each of the prominent diseases occur, and the conditions under which it does not occur,—knowledge which must be gained if we are ever to be able to avoid or control those conditions which are now permitted to cripple and to destroy so many prematurely.

METEOROLOGICAL AND OTHER CONDITIONS MUST BE KNOWN.

In order to build up a sanitary science which shall serve as a basis for the prevention of sickness and deaths, it is essential, as has already been said, to have facts from more

sources than one. It is not enough to know that there are more deaths from inflammation of the lungs in winter, and more from diarrhœa in the summer,—we need to know to what condition of the air, what condition of the body, or of its surroundings, the increase of deaths or of sickness is due, before we can consider the best methods for changing or for avoiding those conditions.

Only by long-continued watching, recording, and studying the meteorological conditions can we learn whether it is the cold, the absence of moisture, the excess of ozone, or the action of the wind, which causes so many more deaths from diseases of the throat and air-passages in winter than in summer, or whether all these are but indirectly related to the subject and the real cause is—as Dr. A. N. Bell has recently suggested—filth, which can easily be removed or avoided. Yet nothing is more certain than that if systematic effort is made we can learn which of the conditions are invariably coincident with the disease and which are only incidentally present; for notwithstanding the fact that in this State the air is generally cold, dry, windy, and contains an excess of ozone in winter, these conditions do not prevail with absolute uniformity, but sometimes one is absent and sometimes another, therefore sooner or later every one of these and other conditions can be compared with the sickness and the deaths from each of the different diseases which now afflict us, and the truth learned as to whether these relations severally or collectively are those of cause and effect. If individual effort could readily achieve this, I think it would have been done long ago; but when the people of a State collect, compile, and publish the material essential for such studies the work has begun, and in this State such a beginning has been made. From the earliest times it has been known that the weather has much to do with health, but at the time the first State report on vital statistics in Michigan was published (for 1867) the compiler gave only a single table of results of meteorological observations, at the Agricultural College, and regretted his inability to secure results of any other observations in the State. It is only within a few years that systematic observations have been taken for the public-health service of the State, and even now no compensation is given for such important service; but philanthropic persons are now prompted to contribute their labours because the State will compile and publish, and thus render their work available for use in sanitary science.

The State Board of Health now receives contributions of meteorological records from about thirty observers in different parts of the State. Each observer makes records of observations three times each day, namely, at 7 a.m., 2 p.m., and 9 p.m.; and he records the facts relative to temperature, humidity, barometric pressure, clouds, winds, ozone, rain, and snow. As these observers "work for nothing and board themselves," they are not expected to add the figures in the several columns for the months; such labours and also computations of the absolute and the relative humidity, computations to learn the actual pressure of the atmosphere, etc., are performed in the office of the State Board at Lansing, where also tri-daily observations are taken. The reports of these thirty or more observers, when added, computed, and averaged, are compiled in tables, showing for each locality the average for each meteorological condition which is observed. These tables may be used for purposes of study by any person. In order, however, to prepare in the best manner possible the statements of the conditions of the air, so that they may most easily be compared with statements of the sickness or deaths from each disease, and an estimate made of the influence upon the disease by each meteorological condition, it has been the custom to so perfect the data that it can be represented to the eye on a diagram drawn accurately to scale. Such diagrams are as useful and as essential to the sanitarian as are the profiles which the surveyor makes for "cuts" and "fills" to the builders of railroads and streets, and their modes of construction and use are similar.

SPECIAL INVESTIGATIONS.

Sanitarians must do more than utilize contributions from meteorology and from

each of the other sciences; they must make original investigations, such as will result in the actual creation of knowledge never before attained; this is the grand mission of sanitary science in behalf of human welfare, and for this sanitarians must face up to nature in ways never before attempted by human beings, and must bring back from this search after revelations, portions of that eternal truth which will teach us the way of life, the way of health, and the way of happiness.

What some of the points are concerning which special investigations are needed, it may not be amiss to say a word here. With regard to small-pox, diphtheria, and scarlet fever, three dreaded diseases which afflict our people, the State Board of Health, in common with the leading men of the medical profession generally throughout the State, already know enough to suppress these diseases if the people could be put in possession of the knowledge and would act upon the information, which however is not likely to be placed before them unless the State Board of Health can have the means for this important service. In fact, small-pox is practically suppressed in Michigan to-day, and diphtheria and scarlet fever have, in many instances in this State, been stamped out of existence in localities where they have appeared. The way to control scarlet fever or diphtheria is not, as seems to be the opinion of many intelligent people and some physicians even, to wait till the disease has taken possession of an individual and then do something to him to kill the disease, provided that the disease does not first kill him, but to keep the disease out of him from the first, by keeping it away from him and him away from it; and to shut the disease into the closest possible quarters and then burn it out or smother it in its most secret lurking-places. This is possible, it is practicable and when all our people join hands to do it, it will be as easy as it is now to keep the wild bears of the forest from our homes; but without efficient local boards of health, and general coöperation by the people, no family can protect itself from either scarlet fever or diphtheria.

With regard to diphtheria, however, there are questions which it would be of use to have decided. We know that the living germs or the poisonous elements which cause the disease are reproduced within the human body, and that in various ways, direct and indirect, the disease is communicated from one person to another; in other words, we know that the disease is *contagious*; whether it is also *infectious*, that is, whether the invisible germs or elements of poison whose presence in the body causes the disease are also sometimes reproduced in substances outside the body, how long they can live (or continue efficient to cause disease) in substances outside the human body, and in what substances they can live and retain their deadly power, are questions the correct and unquestioned answers to which would be of great use in preventing the disease and in destroying its cause. It would also be of service to know what it is that makes some epidemics of diphtheria much more malignant than others, for thus we may be able to substitute mild for malignant epidemics, in some such way as is done for small-pox.

We know that the typhoid-fever poison is communicated by water and by milk; but we need investigations to learn in what other ways it may be communicated, and how it is propagated, whether always in the body or sometimes outside the body, and in what lower animals.

There is much, too, that needs to be known concerning consumption, a disease of which more is said in another part of this paper.

The question of the causation of intermittent fever, or fever and ague, as it is called, which we now know to cause more sickness in Michigan than does any other disease, is still an unsettled question; and while much has been done towards preventing it, by drainage, by cultivation of the soil, and by planting of trees, it would be a great boon to the people of this State if we could know certainly what are the relations of intermittent fever to marsh land, or what it is connected with overflowed land that so greatly favours the disease, what are the conditions both subjective and objective under which ague is certain to arise, what is the specific poison of the disease, if such there be.

CLIMATIC DISEASES MAY BE CONTROLLED OR AVOIDED.

With increasing facilities for travel it may soon be practicable for human beings to gain as much control over their climatic conditions as the wild geese have so long enjoyed; but before this can be realized we must know as much as the geese do,—for they seem to have gained that knowledge which mankind are so slow in gaining, and for the attainment of which I am pleading, namely such knowledge as will enable any person to know the special danger at each age and at each season of the year in each habitable portion of the earth. But, because of the expenses of travel and the many difficulties in the way of periodical movements of the population, I would not be content to stop with the knowledge of a wild goose. There *are* animals which know enough to take care of themselves in warm or in cold seasons of the year, particularly in climates so favorable as that in Michigan; and I see no reason why men may not eventually learn to do as well, if only they will admit the feasibility of so doing, and will devote a necessary part of their energies to this undertaking. In order to accomplish it, however, it seems to me essential that there shall be organized effort, and especially that those whom we elect to apportion the expenditures of the State, in the interest of the whole people and not for the exclusive benefit of local or class interests, shall understand the aims and purposes of the systematic study of the causes of sickness and deaths, and shall recognize those purposes as high and noble.

I hope no one will infer that in this paper all the work of the State Board of Health is mentioned; in view of the many other labours by the Board, and by individual members of the Board, it is my duty to say that this paper relates only to a small part of the work of the Board, a part which less than many other parts has to do with its every-day work at the present time, such, for instance as the dissemination of information already gained; yet it seems to me that it is work which it is absolutely essential to have done in order that in the future progress in sanitary science and service may be possible; and it cannot be done except by thorough coöperation among several classes of people. The purpose of this paper is, therefore, the hope of creating a greater interest in a subject which I deem of vital importance to our fellow-men.

ANNOUNCEMENTS.

Part III. of the "Scientific Roll" will be commenced, if life and health and support be granted to the Conductor, in 1883. In order that the Bibliography may be as full as possible, authors and publishers are respectfully solicited to send copies of, or references to, all their publications dealing with the barometrical condition of the air.

As soon as 200 persons have expressed a wish to subscribe for any one of the subjects mentioned below, the publication of that section of the "Scientific Roll" will be forthwith commenced. The subscription price will be 7*s.* 6*d.* and 10*s.* for each volume, according as the residence of the subscriber is at home or abroad. Each volume will comprise from 400 to 500 pages; and each volume will, in most cases, contain two or more parts, each of which may be subscribed for separately. The extent of these parts will depend upon the amount of matter in hand, so that the subscription price for each cannot be fixed at present, but will be settled when the publication of each part is commenced. The following is a list of the principal subjects:—

Atmosphere, Water, Ocean, Rivers, Lakes, Springs, Glaciers. Land, Elevation and Subsidence of Land and Sea-Bottom, Denudation, Orography, Earthquakes, Volcanoes, Marshes, Minerals, Stratigraphy, Rocks, Plants generally and in classified groups; Animals generally; Protozoa, Actinozoa, Hydrozoa, Echinodermata, Crustacea, Scolecida, Annelida, Mollusca, Myriapoda, Arachnida, Rhynchota, Orthoptera, Diptera, Coleoptera, Lepidoptera, Neuroptera, Hymenoptera, Pisces, Amphibia, Reptilia, Aves, Mammalia, and Man.

Subscribers' names only are asked for now. The sending of these will not involve any pecuniary liability, but will simply be taken as implying that the senders take an interest in the work, and will probably undertake to subscribe when asked to do so.

AQUEOUS VAPOUR: NOTES.

1824.

Dalton, John. Reprint from '*Mem. Phil. Soc., Manchester.*' Read Feb. 9, 1821. (*ra.*)

(*Page* 2) In 1801 I first announced the notion of an aqueous vapour atmosphere distinct from the general atmosphere. If this idea be true, there should be a decrease in density in ascending in a geometrical progression to increments of height in arithmetical progression. I have tested this idea on Helvellyn and other heights by measuring (*Page* 5) the dew point by means of cold water poured into a glass tumbler, or where water was wanting, by means of pounded nitre and sal-ammoniac, or by means of snow. (*Page* 20) [He gives a large number of observations which are of local importance only.] The conclusions are. 1. That the quantity and density of vapour is constantly (or with very rare exceptions) less the higher we ascend. 2. That wherever a dense cloud or fog exists there the temperature of the air and the dew point are the same. 3. That when a mountain is wholly or in great part enveloped in fog there is little variation in ascending either in the temperature of the air or in the dew point. 4. That on the average the dew point sinks 1° for every 100 yards of ascent. 5. That the phenomena of aqueous meteors, such as rain, fog, dew, etc., depend upon the known relations of heat and water. Electricity appears to be a consequent rather than an agent in the formation and decom- (*Page* 21) position of clouds. As the dew point and temperature of the air approximate in proportion as we ascend, at some height they must become the same; and hence the cause why the upper regions of the atmosphere are so frequently clouded; also why the mossy summits of mountains are generally moist. The following represents the drying power of the air according as its temperature is above that of the dew point.

D. P.	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°
30°	8	16	24	32	41	51	63	74	86	98
35	9	17	26	37	48	61	72	85	99	114
40	10	22	33	45	57	71	85	100	117	135
45	12	24	37	51	66	81	99	117	135	154
50	14	28	43	60	78	96	115	135	155	178
55	16	33	51	69	88	109	131	155	181	209
60	18	37	57	77	100	126	153	182	213	244

1827.

Daniell, J. F. (*B.* 1827, 1.)

(*Page* 119.) At about 9890 feet. [1st ed. has 9840.]
(*Page* 164.) .149 [in second col. is a misprint for .140].
(*Page* 176.) .00725 [not .00720 as in 1st ed.].
(*Page* 177.) [The table as given differs materially from that in 1st ed. in the way indicated below, the differences only being given.]

	1st col.	2nd col.	3rd col.	4th col.	5th col.
	0	[All — for +	+.0227	[This col.	1.0703
	1	down to 31.]	[and + is	is unaltered.]	1.0679
	2		substituted for		1.0655
	3		— all down the		1.0631
	4		column.]		1.0607
	5				1.0583
	6				1.0559
	7		.00298		1.0536
	8		.00308		1.0512
	9		.00318		1.0489
	10		.00328		1.0466
	11		.00344		1.0442
	12		.00358		1.0419
(*Page* 178.)	13		.00372		1.0396
	14		.00385		1.0373
	15		.00398		1.0350
	16		.00412		1.0327
	17		.00425		1.0304
	18		.00439		1.0282
	19		.00452		1.0260
	20		.00469		1.0239
	21		.00489		1.0215
	22		.00509		1.0194
	23		.00529		1.0171
	24		.00549		1.0148
	25		.00570		1.0125
	26		.00590		1.0104
	27		.00610		1.0082
	28		.00631		1.0061
	29		.00651		1.0041
	30		.00671		1.0017
	31		.00698		.9995
	32		.00725		.9973
	33	[All + instead	.00752		.9952
	34	of — from 33	.00779		.9927
	35	to 90.]	.00806		.9909
	36		.00834		.9887
	37		.00864		.9867
	38		.00889		.9846
(*Page* 179.)	39		.00915		.9824
	40		.00942		.9804
	41		.00983		.9783
	42		.01024		.9761
	43		.01064		.9741
	44	.02499	.01105		.9720
	45		.01146		.9699
	46		.01187		.9679
	47		.01228		.9658
	48		.01269		.9636
	49		.01310		.9616
	50		.01351		.9596
	51		.01399		.9575
	52		.01447		.9555
	53		.01502		.9535
	54		.01557		.9514
	55		.01612		.9494
	56		.01667		.9474
	57		.01723		.9453
	58		.01784		.9433
	59		.01843		.9414
	60		.01902		.9394
	61		.01961		.9374
	62		.02020		.9354
	63		.02093		.9334
	64		.02166		.9314
(*Page* 180.)	65		.02239		.9274

1st col.	2nd col.	3rd col.	4th col.	5th col.
66		.02312		.92 [Type damaged. See 1845 ed., vol. ii. p. 43.]
67		.02386		.92 5 [type damaged]
68		.02466		.9235
69		.02546		.9216
70		.02634		.9196
71		.02725		.9177
72		.02817		.9157
73		.02912		.9137
74		.03011		.9117
75	.08958	.03114		.9098
76		.03221		.9079
77		.03327		.9059
78		.03438		.9039
79		.03548		.9020
80		.03663		.9001
81		.03781		.8982
82		.03903		.8962
83		.04029		.8943
84		.04159		.8924
85		.04293		.8905
86		.04431		.8885
87		.04573		.8867
88		.04716		.8847
89		.04858		.8828
90		.05005		.8809

(*Page* 181.) To find the specific gravity of any mixture of air and aqueous vapour by means of this table, proceed thus. Note the temperature and the point of condensation by the hygrometer; if they coincide, that is to say, if the air be in a state of saturation, we shall find the specific gravity required in the fifth column opposite to the proper degree of heat in the first column. If the point of condensation be below the temperature, we must look for the alteration of volume due to the heat in the second column, and for the expansion due to the vapour in the third column. Add these together if they have like signs; or subtract one from the other if they have different signs. As the volume corrected by this quantity is to the original volume, so is the standard specific gravity to the specific gravity as affected by the expansion or contraction. To this must be added the increase of weight due to the vapour in the fourth column, and the result will be the correct specific gravity sought. For example, if you wish to know the specific gravity of a mixture of air and vapour of the temperature of 60° and of which the dew point is 40°, we find in the second column opposite to 60° the number +.05833, and in the third column opposite to 40° we have +.00942; the sum of which is +.06775; therefore 1.06715 : 1 : : 1 : .93659. In the fourth column opposite 40° we find +.00580, and .93659+.00580=.94239 which is the correct specific gravity under the assumed circumstances. Something appears to be still wanting to complete the investigations (*Page* 489) of De Luc, De Saussure and Dalton, and to follow up the results to their ultimate consequences. It is a well known fact that water under all circumstances is (*Page* 490) endued with the power of emitting vapour of an elastic force proportioned to its temperature. It is also well understood that the gaseous atmosphere of the earth in some degree opposes the diffusion, and retards the formation of this vapour not by its weight or pressure, but by its vis inertiæ. It may facilitate the comprehension of the subject to distinguish three cases with regard to the evaporating fluid: the first, when its temperature is at the boiling point; the second, when it is below the boiling point but above that of the surrounding air; the third, when it is below that of the atmosphere. The first does not bear upon the subject in hand. In the (*Page* 491) second case the exhalation is proportionate to the difference of temperature. The gaseous fluid in contact with the surface becomes lighter by the abstraction of portions of the excess of heat, and rising up carries with it in

its ascent the entangled steam. This is precipitated, and in the form of cloud is exposed to the third species of evaporation. This process is not only proportional to the difference of temperature and the elasticity of the vapour, but is also governed by the motion of the air. A current of wind tends to keep up that inequality of heat on which it depends, and prevents that equalization which would gradually take place in a stagnant air. Such is the evaporation which often takes place in this climate in autumn from rivers, lakes, and seas, and which is indicated by the fogs and mists which hang over their surfaces. It is, however, the third modification which is the most interesting in the point of view which I have suggested. When the temperature of water is below that of the atmosphere it still exhales steam from its surface, but in this case the (*Page* 492) vapour, neither having the force necessary to displace the gaseous fluid, nor heat enough to cause a circulation which would raise it in its course, is obliged to filter its way slowly through its interstices, and the nature of the resistance it meets with is the first object of investigation. The force of vapour at different temperatures has been determined with great accuracy, and the amount of evaporation has been shown to be, *cœteris paribus*, always in direct proportion to this force. The quantity is also known to depend upon the atmospheric pressure, but I know of no experiments which establish the exact relation between the two points. I attempted to elucidate the point as follows, viz., by enclosing in a glass receiver upon the plate of the air pump a vessel with sulphuric acid and another with water; and by properly adjusting the surface of the two it is easy to maintain, in the included atmosphere of permanently elastic fluid, an atmosphere of vapour of any required force; or in the usual way of expressing the same fact, the air may be kept at any required degree of dryness. The density of air in such an arrangement may of course be varied and measured at pleasure. Now there are three ways of estimating the progress of evaporation in such an atmosphere: the first and most direct is to weigh the loss sustained by the water in a given time; the second, to measure by a thermometer the depression of temperature of an evaporating surface; and the third, to ascertain the dew point by means of the hygrometer. (*Page* 493) [Experiment 1 showed that water at 56° and 58° over sulphuric acid in an air pump receiver could not maintain an atmosphere of vapour of elasticity .068 in., no dew being deposited at 26° nor at 0°. This degree of dryness is less than 129; satura- (*Page* 494) tion being 1000. The air was equally dry in the most highly rarefied air obtained, as shown in experiment 2.] Experiment 3. With the temperature at 45° and the height of the barometer 30.4 in., the water lost by evaporation 1.24 grain in (*Page* 495) half an hour. It was replaced and the air rarefied to 15.2 in.; in half an hour at 43°, the loss was 2.72 grains. The loss from evaporation in equal intervals, with a pressure constantly diminishing one half, was found to be as follows :—

Pressure.	Temperature at Beg.	Temperature at End.	Loss in grains.
30.4 in.	45°	45°	1.24
15.2	45	43	2.87
7.6	45	43	5.49
3.8	45	43	8.80
1.9	45	41	14.80
.95	44	37	24.16
.47	45	31	39.40

When the exhaustion was pushed to the utmost the gauge stood at 0.07, and the evaporation in the half-hour was 87.22 grains. Now, before we infer from these experiments the state of evaporation from different degrees of atmospheric pressure, it is necessary to apply a correction for the variation of temperature. The quantity of evaporation having been determined to be in exact proportion to the elasticity of the vapour, we must estimate the latter from the mean of the temperatures before and after the experiments, and calculate the amount for any fixed temperature accordingly; but (*Page* 496) as the thermometer was in the water it would not give the correct tempera-

ture of the surface. The following table presents us with the former results so corrected for the temperature of 45° :—

Pressure.	Grains.
30.4 in.	1.24
15.2	2.97
7.6	5.68
3.8	9.12
1.9	15.92
.95	29.33
.47	50.74
.07	112.32

Notwithstanding the slight irregularity of the above series, we can, I think, run no risk in drawing from it the conclusion that the amount of evaporation is, *cœteris paribus*, in exact inverse proportion to the elasticity of the incumbent air; and that De Saussure was misled by his hygrometer when he inferred from its indications that a diminution of one-third the density doubled the rate. There is an apparent discrepancy between Dalton's results and mine under the full atmospheric pressure. He found it to be 1.26 grains per minute from a vessel 6 in. in diameter at 45°; this would give 7.65 grains in half an hour from the glass of 2.7 in. diameter. Dalton's experiments were, (*Page* 497) however, made at a temperature above that of the surrounding medium, which caused a current in the latter which greatly accelerated the process. Dalton found that a strong wind would double the evaporating effect. Experiment 4. This was intended to determine whether the elasticity of the vapour varied with the pressure. The sulphuric acid was placed in a vessel 2.8 in. in diameter. The temperature of the water and air was 52°, and the height of the barometer 29.8. The following table shows the dew point which was obtained at intervals of half an hour at different degrees of atmospheric pressure:—

Bar.	Temp. of water and air.	Dew point.
29.8 in.	52°	36°
14.9	53	37
7.45	52	35
3.72	53	36
1.86	52	34
.93	52	36
.15	52	36

The differences are so small that we may regard them as errors of observation, and conclude that the elasticity of vapour given off by water of the same temperature is not influenced by differences of atmospheric pressure. The equal surfaces of sulphuric acid and water here made use of maintained at 52° a degree of saturation equal to 570. At (*Page* 499) 61° the amount of saturation was 651; an increase evidently dependent upon the force of the vapour, but not in exact proportion to its augmentation. Experiment 5. I next tried in what degree the temperature of an evaporating surface would be influenced by differences in the density of the air by means of the following apparatus. To a brass wire sliding through a collar of leathers, in a ground-glass plate, I attached a very delicate mercurial thermometer; this was fixed air-tight upon the top of a large glass receiver, which covered a surface of sulphuric acid of nearly equal dimensions with its base. Upon a tripod of glass standing in the acid was placed a vessel containing a little water into which the thermometer could be dipped and withdrawn by means of the sliding wire. The bulb of the thermometer was covered with filtering paper. At the commencement of the experiment the barometer was at 30.2 in., and the temperature of the air at 50°. Upon withdrawing the thermometer from the water it began to fall very rapidly, and in a few minutes reached its maximum of depression. The following table presents the results of the experiments for different degrees of the air's density; the intervals were each of twenty minutes:—

	Bar.	Temperature of Air.	Temperature of Wet therm.	Diff.
	30.2 in.	50°	41°	9
	15.1	49	37	12
	7.5	49	34	15
	3.7	49.5	31.5	18
(*Page* 500.)	1.8	49.5	28.5	21
	.9	49	24.5	24.5
	.4	49	23	26

In the case of the first the 9° was produced in ten minutes, and the water evaporated from the thermometer not more than $\frac{1}{100}$th of a grain. The depression increased with the rarefaction of the air in the proportion of an arithmetical progression to a geometrical one. The increase is attributable, not to the augmented quantity of the evaporation, but to the decreased heating power of the atmosphere. We may conclude that the (*Page* 501) temperature of an evaporating surface is not affected by the mere quantity of evaporation. These few simple facts appear to be intimately connected with the solution of some very important atmospherical phenomena. The aqueous fluid is so abundantly spread over the face of the earth that there can be no doubt that the permanently elastic atmosphere which surrounds it would very speedily be saturated with its steam, did not some cause, analogous to the sulphuric acid in the receiver, prevent its universal diffusion. This never-failing cause is inequality of temperature. As in the smaller experiment we found that the degree of dryness was proportional to the energy of the absorbent mass, and that the existing vapour was equally diffused between it and the exhaling surface, so, in the larger operation of nature, we shall find that the state of saturation is dependent upon the point of precipitation, and that the (*Page* 502) aqueous vapour is nearly uniform between it and the source of steam. Now it is well understood that the temperature of the gaseous atmosphere in its natural state must decrease with its density as we ascend to its upper parts; so that a great degree of cold is at all times to be found within a very moderate distance from the surface of the waters. It is this low tension which determines the tension of the aqueous vapour; and it is evident that the evaporation which is thus caused at the base of the aerial fluid, must be accompanied by a simultaneous and equal precipitation above. What then becomes of the precipitated moisture? Let us endeavour to trace the order of this phenomenon. We will first suppose a calm state of the atmosphere, a temperature of 80°, and a barometer at 30 in. at the surface of the earth. By a calm state of the atmosphere is here meant one that is free from any lateral wind, and in which, the only currents being in an ascending and descending direction, evaporation would proceed at the rate exhibited in the first column of Dalton's table. The dew point at the surface of the earth is 64°, and this is determined by the temperature at the height of about 5000 feet, where the barometric column would maintain itself at 24 in. The degree of saturation would therefore be 600, and the amount of evaporation 1·74 grain per minute from a surface of 6 in. in diameter. This quantity we therefore suppose condensed at the height above named. But the state of saturation in the (*Page* 503) atmosphere above this point of precipitation is again diminished: for we may suppose the force of the vapour to be determined by a temperature of 31° at a height of 15,000 feet, where the barometer would stand at about 16 in. The force of evaporation would therefore be 1·71 grain per minute at the full atmospheric pressure; and this amount increasing as the pressure diminishes would give 2·13 grains per minute: so that the power of evaporation at this stage exceeds the supply of moisture, and no cloud could possibly be formed. Above the second point of condensation let us now suppose the force of vapour to be determined in still loftier regions by a temperature of 12°. The force of evaporation would then be 0.44 grain increased in the proportion of 16 in. to 30 in. or 0.82 grain. Here then the power of evaporation would be insufficient to diffuse in the upper regions the whole of the moisture supplied from the surface of the earth, and a cloud, it might be supposed, must consequently result.

But another modification of the process now ensues: the precipitated moisture has a tendency to fall back into the warm air below it, and consequently would assume the elastic form with a rapidity proportioned to the rarefaction of the stratum in which it is diffused. There is I think no difficulty in supposing that no visible cloud, or one of extreme tenuity, would be formed during this double process of evaporation. A very important reaction, however, must take place upon the strata of vapour beneath; the elastic force being increased above enables the water below to maintain an atmosphere (*Page* 504) of a higher degree, and the quantity of evaporation must decrease as the point of saturation rises. A different arrangement of the points of precipitation would ensue in the progress of these effects. An important distinction must here be drawn between the ultimate effects of the superior and inferior evaporation denoted above. In the first the whole weight of water is condensed and simultaneously exhaled, and although it constitutes steam of an inferior degree of force, there is little or no difference in the quantity of its latent heat and no effect is produced upon the temperature of that portion of the atmosphere in which the change takes place. But in the second the condensation happens at one spot and the vaporization at another inferior to it; the latent heat is therefore evolved at the former and communicated to the air, while at the latter this process is reversed and the air is cooled. The process of this operation would therefore tend to equalize the temperature. We will next imagine that the surface of the earth is swept by a high wind, and that the atmosphere, instead of resting calmly upon its base, moves laterally with great velocity. Under these circumstances experience has shown that the amount of evaporation will be nearly doubled; but the force of evaporation is not altered in the upper regions. The inferior exhaling surface being immovable, the motion of the air perpetually changes and renews the point of contact, and prevents accumulation at any one place; but in the heights of the atmosphere the exhaling surface of the clouds is borne upon the wind and their relative situations never change. The progress of precipitations must, (*Page* 505) therefore, necessarily, under the circumstances, outstrip that of evaporation, and the disturbance of the atmospheric temperature will be greatly accelerated. There is another cause which would also quicken evaporation below without equally increasing its power of diffusion at any given height above; and that is a decrease in the density of the air at the surface of the earth. Under the circumstance of our first supposition, imagine the barometer to fall to 28 in., the evaporation would be increased from 1.74 grain to 1.86 grain per minute; but this decline of 2 in. at the surface would indicate a contemporaneous fall of little more than 1 in. at the height of 15,000 feet, and the rate of diffusion would vary accordingly. When it is considered that great falls of the barometer are generally accompanied by high winds, and that this disparity is multiplied by the force of the current, it is easy to appreciate the influence of this local increase of the power of evaporation. The facility of evaporation in the rarer regions of the atmosphere will also go far to account for the state of saturation in which the air of mountainous regions is generally found, and many minor meteorological phenomena might probably meet with their explanation from variation of the same cause: such as the fogs which frequently accompany a very high degree of atmospheric pressure, and (*Page* 506) that peculiar transparency which often precedes rain, and is accompanied by a falling barometer. These ideas are supported by De Luc's accurate observations. At first sight we might regard mountain fogs as permanent; that the evaporation has reached its maximum owing to the air being saturated; and that the vesicles of vapour remain for weeks or months. But the real state of things is quite different: evaporation still continues from the surface of water, the vaporous vesicles are constantly rising (*Page* 507) and evaporation is reassumed on the surface of the fog. It is an interesting and instructive sight to see such a surface below one in a valley, and in the distance the brown slopes of a mountain. Such a valley, when lighted up by the sun, seems to be filled with cotton drawn out into myriads of threads, protuberances appear everywhere,

as though a spinner was drawing threads from the mass, and they disappear in succession as they dissipate into the air. Occasionally these protuberances are elongated and detached from the main mass as they rise; we then see it like a film of gauze, which gradually vanishes. Fogs then are constantly being formed on the ground and as constantly being dispersed in the air, and yet there is no increase of humidity (Idées, xi. p. 78). Since I have changed my opinions as to the cause of rain, I have constantly watched the clouds, and readily perceived that they may enlarge, even while in process of evaporation. If one gazes on their scooped edges, which present such a variety of shapes against the clear blue sky, it often happens that the part on which we fix our (*Page* 508) attention vanishes *in situ;* often we see it extend while the cloud has shown no apparent movement, nor decrease of size. Sometimes while we see one piece disappear, others may be seen in process of formation, producing festoons, which increase the size of the cloud; at other times the cloud is lessened, and then all its festoons vanish; we perceive that at the same time the cloud thins and totally disappears. Hence I am inclined to believe that there is in the air a general source of vapour; that these vapours are produced at the place where the cloud is formed; that it is by the persistency of this vapour production that clouds are sustained, and even grow in size in spite of the continuance of evaporation, and that their disappearance is due to the rate of evaporation exceeding that of supply (tome xi. p. 117). It has been said that vapour condensation would supply but a trifling amount of heat, but the evolution (*Page* 509) of caloric is by no means so small as supposed. The condensation of a pound of steam would raise the temperature of 3567 cubic feet of air 10°. The water which falls represents only a portion of the condensation which occurs in the air. Looking at this, we shall perhaps have a juster notion of the prodigious power of atmospheric vapour.

[The following remarks down to p. 530 are from a paper read to the Hort. Soc. on Aug. 17, 1824.]

(*Page* 513.) The changes of moisture extend from 1.000 [corrected to 1000 in the 1845 ed.] or saturation to 389. The amount of evaporation from the soil, and of exhala-(*Page* 514) tion from the foliage of the vegetable kingdom, depends upon two circumstances: the saturation of the air with moisture, and the velocity of its motion. They are in inverse proportion to the former and in direct proportion to the latter. The horticulturist cannot control the saturation, but he has some command over the velocity. He can break the force of the blast by screens, or may find natural shelter in situations on hill-slopes. Excessive exhalation is very injurious to many of the processes of vegetation, and no small proportion of what is commonly called blight may be attributed to this cause. Evaporation increases in a prodigiously rapid ratio with the velocity of the wind, and anything which retards the motion of the latter is very efficacious in diminishing the amount of the former, the same surface which in a calm state of the air would exhale 100 parts of moisture would yield 125 in a moderate breeze, and 150 in a high wind. The dryness of the air in spring renders the effect most injurious (*Page* 515) to the tender shoots of this season of the year, and the easterly winds especially are most to be opposed in their course. The moisture of the air flowing from any point between N.E. and S.E. inclusive, is to that of the air from the other quarters of the compass in the proportion of 814 to 907 upon an average of the whole year, and it is no uncommon thing in spring for the dew point to be more than 20° below the temperature of the atmosphere in the shade, and I have even seen the difference amount to 30°. [His observations were in all probability made in England and near London.] The effect of such a degree of dryness is parching in the extreme, and if accompanied with wind is destructive to the blossoms of tender plants. Hence screens to the N. and E. are protective to plants. The south aspect of walls has an exalted temperature, but the air is extremely dry. This would cause such an exhalation from the blossoms of tender fruit-trees as to be detrimental to them. Such plants should perhaps be

(*Page* 516) partially shaded. In May I have seen the thermometer in sun at 101°, and the dew point at 34°; this gives a dryness of 120. The shelter of a mat would often suffice to prevent injury. Some of the present practices of gardening are founded upon experience of similar effects; and it is well known that cuttings of plants succeed best in a border with a northern aspect protected from the wind; or if otherwise situated they require to be screened from the force of the noonday sun. If these precautions be unattended to they speedily droop and die. For the same reason the autumn is selected for placing them in the ground as well as for transplanting trees; the atmosphere at that season being saturated with moisture is not found to exhaust the plant before it has become rooted in the soil. Over the absolute state of vapour in the air we are wholly powerless; and by no system of watering can we affect the dew point in the free atmosphere. This is determined in the upper regions. It is well known to (*Page* 519) gardeners that less dew is formed under a tree or hedge than in places which are wholly exposed. To vegetation growing in the climates for which they were origi- (*Page* 520) nally designed by nature, there can be no doubt that the action of radiation is particularly beneficial from the deposition of moisture which it determines upon their foliage. But to tender plants the extra cold may be highly prejudicial. It also appears probable from observations that the intensity of the action increases with the distance from the equator to the poles; as the lowest depression of the thermometer which has been registered between the tropics from this cause is 12°, whereas in the latitude of (*Page* 522) London it not unfrequently amounts to 17°. In the hothouse the plants (*Page* 524) are natives of torrid places having hot and very vaporous atmospheres. Captain Sabine found it to be between about 730 and upwards. In hothouses the (*Page* 530) degree of moisture often falls short of 500. The dry air often induces (*Page* 561) excessive evaporation in plants, which injures them. That part of the Continent of Europe over which our observations [on the barometer] extend, lies about midway in the course of the antagonist currents in the atmosphere; which from the distribution of the temperature of the globe must, in an undisturbed state of a gaseous fluid, flow between the poles and the equator. The whole line of its northern extremity, however, is bounded by the ocean, the evaporation from which must constantly disturb that regular progression of temperature upon which the balance of the two streams depends. It is by the heat evolved from the condensation of the rising vapour in the upper regions, and by the cold communicated by its rapid re-evaporation that such inequalities are produced. The actions and consequent reactions produced by these irregularities we find constantly communicated from the north, where they originate in a (*Page* 562) decreasing degree, to the south. The northern ocean is exactly situated in the best position with regard to the Continent of Europe for producing powerful effects; by its means the warm waters of the Atlantic are brought into contact with the cold winds and ice of the Arctic regions. In such a combination of circumstances evaporation and condensation must reach the most violent extremes, particularly in the spring and autumn of the year. The precession of the western before the eastern curves [of (*Page* 563) the barometric condition] may be explained by the situation of the immense reservoir of vapour which is continually rising from the Atlantic Ocean; this when wafted by the currents to the northern shores of Europe can only progressively exert its influence along the successive meridians. Captain Basil Hall has favoured me (*Page* 593) with an illustration of the fact that the vapour of the atmosphere is arranged in beds of equal density from observations made by him on the peak of Teneriffe.

(*Page* 596.) Elastic force of aqueous vapour calculated by Galbraith, 0° — 124° F.

1832.

Hilhouse, William. (*B.* 1832, 2.)

(*Page* 241.) The evaporation in the neighbourhood of the line being supposed ten times greater than near the poles, the rains are in proportion much more heavy and frequent. (*Page* 242.) Woody countries are always the most humid.

1833.

Ainsworth, W. (*B.* 1833, 1.)

(*Page* 213.) During Captain Beechey's expedition observations were made on the humidity of the air in different parallels.

1834.

Ainsworth, William. (*B.* 1834, 1.)

(*Page* 71.) The diaphanous character of the air (Humboldt) at once increases the radiation of the plains and the power of transmission of the radiated heat. Jacquemont attributed the inequality in the height of the snow line on the two sides of the Himmalayeh to the serenity of the plains of Ladauk and the foggy climate that reigns in the Hindoostan side.

Campbell. (*B.* 1834, 2.)

(*Page* 148.) At Melville Isle [off N. Australia], when the N.W. monsoon terminates in April the sky becomes clear, the air dries, while the rain ceases. During the dry season (*Page* 149) there are frequent heavy dews at night.

Jackson, J. R. (*B.* 1834, 3.)

(*Page* 84.) What is a fog, a haze, a thick atmosphere? The transparency of the air is relative till its measure be determined, and that in a manner not dependent on the greater or less perfection of the observer's sight. In making observations of evaporation (*Page* 235) the same hours should be kept in order that the reference may always be to the same twenty-four hours. Particulars should be entered of the appearance of clouds. (*Page* 237) In the case of evaporation the sum of the quantities should be given.

Parish, Woodbine. (*B.* 1834, 4.)

(*Page* 95.) In East Falkland Island fogs are frequent, especially in autumn and spring, but they usually dissipate towards noon.

1835.

Committee of the S. African Lit. & Phil. Institution. *Journn. Roy. Geog. Soc.* vol. v. (1835). (*rvp.*)

(*Page* 376.) The best measure of the momentary evaporative power of the air seems to be the depression of the wetted thermometer below the dry one. But the actual evaporation from a given surface is quite another thing, and a question may be raised how far any useful approximation to a knowledge of the total evaporation from an extensive and (*Page* 377) diversified surface unequally moistened and variously exposed to the sun, defended by clouds or refreshed by dews, can be obtained by any small or local experiments. In hot arid climates the effects of copious dews must be separated from that of rain. Attention to the amount of dew is very necessary, not only because the meteorological questions involved are of a high degree of interest generally, but because

in arid climates the dews are of almost as much importance to the maintenance of (*Page* 378) vegetation as the rain. In connection with wind it is important to observe the connection of cloudy weather with the quarter from which the wind blows, or has blown for some time previous, and the usual character of the winds as to moisture or dryness. In describing the state of the sky as to clouds, etc., the observer will bear in mind that it is only in that region of the sky which is vertically above him that the true form and outlines of the cloud are exhibited, and the area they cover, as well as the intervals between them, distinctly seen. As they approach the horizon in any direction their extent is foreshortened by perspective, their apparent magnitude diminished by distance, and their intervals covered in and hidden by their mutual interposition. In estimating, therefore, the quantity of clouds in the sky, regard must be had to this, and our judgment should rather be formed on a view of the region extending from the zenith every way half down to the horizon than from the aspect of the heavens below that limit. It would be better to notice both and to state separately the proportions in which each are covered, and the quarter of the horizon towards which the chief masses in the lower region lie. The general aspect of clouds should be noticed, and especially the height of the lower surfaces, or the level of the vapour planes should be estimated. In a mountainous region this is easy so long as the vapour plane is below or not far above the summits of the hills; and in such regions the formation and dissipation of clouds in the neighbourhood of the mountain summits under the influence of certain winds forms an interesting study. The formation of clouds at night under the influence of a gradually descending temperature is a point worthy of attention. It frequently happens that without any perceptible wind the sky will suddenly become hazy in some one point, and the haze condensing and spreading in all directions without a wind, the whole heavens will (*Page* 379) become overcast in a remarkably short time. The same thing will sometimes occur nearly at the same hour for many nights in succession. The height and thickness of the cloud-strata, their connection with cross or opposite currents of wind in the regions where they subsist, and the laws of their formation and intermixture, deserve to be studied with care; and with reference to the hygrometric state of the air at the time and place, and for several hours before and after.

Coulter, Dr. *Journ. Roy. Geog. Soc.*, vol. v. (1835.) (*rvp.*)

(*Page* 69.) The air about Aqua Sola, California, is excessively dry. The severe cold felt in some places must be attributed to this extreme dryness. The great heat experienced at Aqua Sola, 140°F., is in part to be explained by the excessively dry air. On the table lands of Mexico the frequent occurrence of frosts is associated with a scarcity of water.

1836.

Fitz Roy, R. *Journ. Roy. Geog. Soc.*, vol. vi. (1836.) (*rvp.*)

(*Page* 334.) Clouds are said to be attracted, if not partly caused, by land or by trees. As the low islands of the Dangerous Archipelago have no hill or height of any kind about which the clouds attracted by them can gather and discharge their contents, whether electrical or fluid, perhaps those clouds wanting a conductor discharge themselves irregularly and in squalls.

1837.

Journ. Roy. Geog. Soc., vol. vii. (1837.) (*rvp.*)

[There is nothing in it for these notes.]

1838.

Page, E. L. *Journn. Roy. Geog. Soc.*, vol. viii. (1838.) (*rvp.*)

(*Page* 319.) At Gualan, June 1834, we were in the rainy season which lasts from April to November, and, although the mornings were fine, at 3 P.M. the clouds gathered on the wooded hills around, lightnings flashed and torrents of rain poured down for about three hours, when the sky cleared and all was bright and calm as a summer's evening in England.

1839.

Richardson, Dr. *Journ. Roy. Geog. Soc.*, vol. ix. (1839.) (*rv.*)

(*Page* 364.) The amount of terrestrial radiation is greatly influenced by the clearness of the sky, and it was often remarked at Fort Enterprise that a clear sky soon after sunset was accompanied by a brilliant aurora borealis, and that this seldom continued beyond midnight, or one in the morning, when it was superseded by fleecy clouds, (*Page* 365) obscuring the blue sky. It often happened that shortly before sunrise the sky again cleared, and it was almost always much colder to the sensations at that time than at any other hour of the night.

Journ. Roy. Geog. Soc., vol. x. (1840.) (*rv.*)

[Nothing in it for these notes.]

1841.

Allen, Bird. *Journ. Roy. Geog. Soc.*, vol. xi. (1841.) (*rvp.*)

(*Page* 87.) On the Belize the long dry season commences in February.

1842.

Bacon, Dr. F. *Journ. Roy. Geog. Soc.*, vol. xii. (1842.) (*rv.*)

(*Page* 201.) About Cape Palmas the dry season commonly includes less than three months in December, January, and February, a state of things strikingly different from the seven, eight or nine months' absolute drought so constant and regular in Senegambia and the adjacent coast. The peculiarity of the seasons here [about Cape Palmas] (*Page* 202) furnishing an abundance of moisture throughout the greater part of the year, gives this country very eminent advantages for the production of rice; which, as is well known, in almost every other part of the world—as in Carolina, India, China, etc.—is confined to low grounds, liable to regular inundation. This is also the case with the northern part of the rice-growing region of W. Africa, from the Gambia to Sierra Leone. But on the Grain and Ivory Coasts, the long and abundant rains furnish a bountiful supply of water to the whole surface, high and low. Along the Gold Coast the period of the rainy season is about the same as that of the western region in the same latitude, but the showers are light and short. This peculiarity of climate has its advantages for maize, which can hardly be ripened in a wet climate. On the windward coast it is plucked while green, as the wet season would seldom permit it to ripen.

Karaczay, Count. *Journ. Roy. Geog. Soc.*, vol. xii. (1842.) (*rv.*)

(*Page* 45.) The signs which in Albania usually foretell the approach of the N.E. wind, called the Bora, are small dark clouds surrounding the summits of the mountains, and moving in different directions; sometimes white clouds of a round form hover over the mountains, and the sea is very low. On the contrary, the scirocco, or scilocco, a S.E. wind, causes the sea to run extremely high. Its approach is indicated by black

clouds covering the mountains, a higher rise of the sea, and an increased temperature. The wind brings much rain.

Schomburgk, Robert H. *Journ. Roy. Geog. Soc.*, vol. xii. (1842.) (*rv.*)

(*Page* 179.) It is well known to the agriculturists [of British Guiana] how beneficially the blocks of ferruginous clay operate on the soil on which they lie, contributing not only to the retention of moisture, which would otherwise evaporate, but to the precipitation of atmospheric vapours.

1843.

Schomburgk, Robert H. *Journ. Roy. Geog. Soc.*, vol. xiii. (1843.) (*rvp.*)

(*Page* 25.) The mauritias grow only in moist soil or swamps, and when we failed to procure water by digging at the foot of their trunks, we knew that our search would prove hopeless anywhere else in the neighbourhood. In April, 1842, the wind near (*Page* 29) Ilami-Kipang, in British Guiana, generally lulled towards sunset, but began to blow hurricane-like from the northern quarter towards 8 o'clock. I observed a black cloud rise about that time on the southern hemisphere [=horizon], which, when it reached the altitude of about 25 degrees, expended [=expanded], and the strong breeze set in. May 13, 1842. Near the sources of the Takutu and Rupununi. The savan- (*Page* 68) nahs present ranges of hills, and the sight of mauritia palms gives hope of water. In lieu of this, however, the ground under the mauritia is as dry as the surrounding savannah.

1844.

Baily, J. *Journ. Roy. Geog. Soc.*, vol. xiv. (1844.) (*rv.*)

(*Page* 129.) Evaporation, according to various calculations, amounts upon an average to about 39 in. per annum in intertropical climates.

Christopher, W. *Journ. Roy. Geog. Soc.*, vol. xiv. (1844.) (*rv.*)

(*Page* 97.) On the Haines river, the driest season is in February and March. The rains commence towards July.

1845.

Daniell, J. F. *Elements of Meteorology.* 2 vols. 1845. (*rvp.*)

(*Vol. I. Page* xxxii.) Sir John Herschel, referring to Daniell's scientific labours, says: "The continued generation of the aqueous atmosphere at the equator and its destruction in high latitudes, furnishes a motive power in meteorology whose modification and the mechanism through which it acts, have yet to be inquired into."

(*Page* 26.) The spontaneous evaporation of water and the diffusion of steam through the air take place doubtless by the same process, and the independence of the aqueous atmosphere is in fact proved by the invariableness of the depression of temperature produced by the evaporation from the surface of any moistened porous body in an atmosphere of any given degree of dryness. The amount of this depression depends solely upon the temperature and upon the dew point, and although the amount of evaporation in a given time is greatly affected by the density and motion of the gaseous medium, the temperature of the evaporating surface and the tension of the rising vapour (*Page* 27) are governed entirely by the elastic force of the steam previously intermingled with it. [In this edition * is placed opposite the figures in table xxvii. as (*Page* 90) indicated in 1823 notes.

* .673	* 67.9	
* .606	* 64.4	* 64.4

'Spring of the' [are words added in this edition, at the passage indicated in notes 1823 ed., p. 58.]

'Re-evaporated' [in place of re-dissolved, in 1823 edition, p. 58.]

(*Page* 95.) [Asterisks added to constituent temperature column of table on p. 62 of 1823 edition opposite 64·4, 12·8 and —30·7.]

'Steam' [for stream, 1823 edition, p. 64].

(*Page* 97.) [* is added to 44.9 in sensible temperature column, and to 64.4 in constituent temperature column. See notes, 1823 edition, p. 64.]

(*Page* 103.) [The decimal point is here prefixed to .368, .507 and .786, omitted in 1823 edition, p. 71.]

(*Page* 108.) 'Elasticity' [substituted for quantity, in 1823 edition, p. 75.]

(*Page* 109.) 'Elasticity of that' [instead of weight in 1823 edition, p. 77], and compound [for natural, 1823 edition, p. 77.]

(*Page* 110.) 'Deposition' [for decomposition in 1823 edition, p. 78], and 13500 [for 3500 on same page.]

(*Page* 113.) '0' [added in place indicated in notes, 1823, p. 80.]

(*Page* 114.) [The following addition is made after 'mixed atmosphere.' See notes, 1823, p. 82.]

The elasticity of the vapour at the surface of the sphere is no guide to the mean pressure of the total aqueous atmosphere; nor by deducting the amount of that elastic (*Page* 115) force from the total atmospheric pressure do we obtain, as has been supposed, the simple pressure of the dry gas; for it must be remembered that from the difference of their specific gravities the principal effect of mixing vapour with an unconfined dry gaseous atmosphere is the expansion of the latter, which, considered alone, like the expansion of heat in a column of air, will cause a different distribution of weight among its upper horizontal sections without proportionally distributing the total pressure at its base.

[Table xxxvi. is referred to. In the copy consulted by me it is placed opposite p. 115 of vol. ii.]

(*Page* 116.) 'Steam' [for stream, in 1823 ed., p. 83].

(*Page* 118.) [Addition to 1823 edition, p. 84. In S. R. notes p. 248, the page 114 was given by mistake for 118.] Neither must we here exclude from our consideration that vertical circulation of the air to which we have before referred as resulting from the ascent of the strata heated by the surface of the sphere and their descent after cooling in the upper regions. It is obvious how the evaporation must be thus accelerated and how the vapour formed in the hotter regions must be transported into the upper current and precipitated from it upon the colder latitudes of the sphere. Indeed there can be little doubt that the first admixture of the vapour itself with the lower stratum will give it a mechanical tendency to rise which will greatly assist the act of evaporation; and there is reason to think that the amount of evaporation experimentally determined by Dr. Dalton in calm weather greatly exceeds that which would result in a confined atmosphere where this mechanical action would be impeded.

(*Page* 133.) [Addition to 1823 ed. p. 94.] The comparative levity of the atmosphere of the southern hemisphere of our globe may probably be accounted for by the permanent expansion produced in it by the perpetual rise and precipitation of aqueous vapour from a surface almost covered with sea, and differing in this respect so materially from the corresponding dry latitudes of the northern hemisphere.

(*Page* 159.) [Addition to 1823 ed., p. 118.] If there be one point of more interest and importance than another in meteorology it is certainly the perpetually varying state of the great ocean of aqueous vapour which permeates the gaseous atmosphere; but it has hitherto been sadly neglected by observers, who, even in the few observations which have been regularly made, have persevered in the use of imperfect instruments when more perfect ones have been at command. We can nowhere find mean results

for every part of the globe comparable with those which we possess for temperature by which to test our theoretical conclusions; but, still, experience as far as it has been recorded, confirms that general distribution of vapour which seemed legitimately to follow from our hypothesis. There cannot be a doubt that on the surface of the earth at the level of the sea, the average elastic force and constituent temperature of the vapour decreases with the mean temperature, and in the immediate neighbourhood of the sea the dew point may be reckoned as two or three degrees below it. In the following table will be found the results of the most authentic observations which have been (*Page* 160) collected upon the subject. Table (xlv.) of the mean dew point and force of vapour in different latitudes on the level of the sea.

Place.	Observer.	Dew point.	Force.
Atlantic between 24° 25′ S. and 27° 50′ N.	Hon. Capt. Spencer	72°	.773 in. mercury.
Do. Gulf of Guinea	Maj. Sabine	74° to 80°	.911
Do. St. Thomas	Do.	71 to 74	.773
Indian Ocean. Bombay	Sykes	73–76	.853
Atlantic. Madeira	Heineker	59.4	.497
Do. London	Daniell	44.5	.290
Polar Sea, 71° 20′—73° 48	Parry	27.6	.157

Mr. Neuber, of Apenrade in Denmark, made observations at Apenrade every two hours for a year from 7 A.M. to 11 P.M. The mean is .346 for the tension of the vapour, and for the several hours as follows (table xlvi.).

7 a.m.	.319	1 p.m.	.374	9 p.m.	.321
9 „	.343	3 „	.372	11 „	.391 [?.319]
11 „	.363	5 „	.358		
12 „	.360	7 „	.332		

The means in table xlv. were based on observations for August and September, and would be greatly above the true annual average.

(*Page* 161.) [Addition to 1823 ed., p. 118.] Saussure remarked that his hygrometer near the surface of the earth proved the air to be removed 30 or 40 degrees from extreme saturation when the presence of clouds in the upper sky demonstrated the perfect humidity of that region. That philosopher often observed this phenomenon when he ascended a mountain whose summit was enveloped in a cloud. On the other hand, he as frequently found that when mists covered the plains and a bright sun gilded the summit of the mountain the limit of extreme humidity was below, and air far removed from saturation above. Bands of clouds he sometimes found to swim between masses of air less humid than themselves.

(*Page* 162.) Colonel Sabine [captain in 1823 ed., p. 119].

(*Page* 167.) [Addition to 1823 ed., p. 126.] The obvious general stratification of the clouds can be accounted for upon no other principle than that of the sudden attainment of the dew point in the rise of different beds of vapour under the control of the natural progression of temperature of the gaseous atmosphere in which they are confined. Had it not been for this provident adaptation of the two elastic fluids to each other, the atmosphere would necessarily have been at all times turbid throughout its depth with precipitating moisture; but as it is, the clouds are confined to definite planes of precipitation. Nothing can be more interesting at times than to watch the indications of those natural hygrometers of the heights above us, and to observe the first precipitation of the moisture of the lower stratum of vapour carried by an almost instant evaporation into vapour of a lower tension to still greater altitudes, again to be precipitated, and again to be evaporated. When indeed the normal progression of temperature becomes necessarily disturbed by the process which we are contemplating, then the depths of air become turbid, the winds arise, and the rains descend, effect their beneficial purpose, and in effecting it restore the more permanent order due to the gaseous

law. Mr. Green has found that the isothermal planes of the atmosphere are parallel, or nearly so, to the earth's surface; so that the aeronaut knows generally, even though the earth may be intercepted by a cloud [he means view of the earth], when he is crossing a chain of hills, because the upper surface of the clouds generally follows in a great measure the configuration of the earth. The upper surface of the clouds, on (*Page* 168) occasions when they overspread the surface of the earth at a moderate elevation, seems to accommodate itself to all the variations of form in the subjacent soil.

(*Page* 178.) It is clear that we must seek for the origin of the greater extra- (*Page* 179) tropical oscillations of the barometer in the irregular convection of heat produced by the formation and condensation of aqueous vapour. The bodily rise of a large (*Page* 199) column of heated air will tend to draw towards its base as to a centre the air from all the surrounding districts; and it will carry with it a sufficient cause for its continual expansion and ascent in the vapour with which it is mixed, and which, by its rapid precipitation, must give out its latent heat. During the blowing of a full harmat- (*Page* 214) tan it has been found that salt of tartar (carbonate of potassa) which had imbibed moisture so as to run upon a tile, became perfectly dry upon two or three (*Page* 215) hours' exposure to the wind; which fact indicates a dew point considerably below the one just mentioned [which was 32°]. Common experience has proved that in all countries the winds which have blown over large tracts of land are much drier than (*Page* 216) those which proceed from the sea. We have two natural hygrometers on a large scale, clouds and rain. Dr. Hutton's explanation of rain is generally accepted. He supposed it to result from the simple mingling together of great beds of air of (*Page* 217) unequal temperatures differently stored with moisture. "A volume of air of a given temperature can be charged with only a limited quantity of humidity, and so long as the temperature remains unchanged the moisture cannot be augmented. As the air cools it approaches to a state of saturation, and is disposed to part with some of its humidity; and on the contrary, when heat is gained at any time by it, the power of receiving more moisture is at the same time obtained, while the union of two volumes of unequal temperatures must chill the one and warm the other, the former will resign some of its moisture and the latter will be disposed to receive it; and had the order of nature permitted these opposite conditions of humidity and temperature to be exactly balanced, the united volume might have preserved its moisture unchanged, and no portion of the vapour whatever have been rendered visible. The mingling of two saturated volumes of air may result in a mean temperature, but a mean degree of moisture cannot result, but some quantity will be found beyond what the mean temperature requires. This quantity, sometimes more and sometimes less, according to the temperature of the mingling volumes, must be discharged in the shape of rain, for the moisture which the air cannot support ought of necessity to descend. If we mix saturated air of 40° and 60°, whose force of vapour would be .263 and .524 in. of mercury, the mixture will have a mean temperature of 50°. The mean elasticity is .393 in., but the elasticity of saturated air at 50° is .375 in., the difference .018 in. is the amount of moisture which must be precipitated." But upon close examination this will appear to be by no means a satisfactory explanation of the process of nature. Indeed, every one may have an opportunity of observing that when vapour of high pressure is suddenly mixed with the atmosphere, it is very seldom precipitated in the form of rain. A copious cloud is indeed formed which speedily evaporates and vanishes into thin air. The fact is that one most important part of the process has been left out of consideration: namely, the enormous quantity of latent heat which is instantly disengaged by the condensation. The cloud is no sooner formed than it is again evapo- (*Page* 219) rated; the warmed air being prepared to support steam, not at once of the full elastic force of the hottest volume of the mixture, but considerably higher than that of the coldest. By slow degrees enormous tracts of the atmosphere have their

natural progression of temperature thus subverted and raised, and are made to support vast beds of moisture far exceeding in amount what could exist in the normal state of the permanent gases. Fresh stores pour in on every side; the process goes on; but the counteraction of the air against this coercion increases in energy; the precipitating process prevails, while evaporation becomes more languid; the clouds increase slowly, approach the earth, the different strata inosculate with each other, and at length descend in rain. The atmosphere gradually discharges its load as the natural progression is restored. In such a saturated state of the atmosphere an artificial shower of rain may be formed by the escape of steam into the air, and occasionally under such circumstances the rushing vapour from steam vessels is partly returned in large drops upon the deck. Mr. Monck Mason has remarked that "whenever from a sky completely overcast with clouds rain is falling, a similar range of clouds invariably exists at a certain elevation above; and that, on the contrary, whenever, with the same apparent condition of the (*Page* 220) sky below, rain is altogether or generally about, a clear expanse of firmament with a sun unobstructed by clouds is the prevailing character of the space above." The transport and mixture of the vapour is partly effected by the convection of the air, and partly by its own diffusive energy. It is carried aloft by the horizontal winds from the hot moist regions of the globe towards the colder dry regions, and it rises from the evaporating surfaces in those rotatory vertical motions which we have noticed as affecting the mixture of the hot and cold particles of the air. But besides these mechanical processes, the process of diffusion by which it permeates the particles of air without disturbing their relative positions is perpetually and energetically acting to spread it from points of greatest to those of least tension, and thus tending to equalize its pressure. The attentive and systematic study of the clouds as they form, dissolve away, and reform in their great successive planes of precipitation, is one of extreme interest, and if properly followed up would explain much that is at present obscure in the process of nimbification. Their language is, however, very difficult to decipher from the difficulty of understanding the perspective of the ever changing masses. They are never at rest; but as they float upon the wind they may be observed to have proper motions of their own. Different portions of their masses will be found to circulate, as the air, heated by the act of precipitation, rolls to mingle with the cooler masses with which it is in contact. It is this rolling motion which gives the infinitely varied rounded contour to (*Page* 221) the cumulated heaps which appear fixed in the distance, but which a near examination proves to be in a state of perpetual change. The process of diffusion is also distinctly marked by the fibrous streaks which may often be seen to shoot and expand from different centres before they have time to accumulate into the larger (*Page* 222) wreaths or denser rolling masses. The diffusive power of the vapour is sometimes attested even against the force of a gentle wind, and the dense fogs which infest the banks of Newfoundland are often observed to advance in a direction contrary to the breeze. The following passages [p. 506–508 of the 1827 ed.] from De Luc's works will afford a complete illustration of the preceding remarks.

(*Page* 224.) The theory of solution will not explain this [i.e. the phenomena observed by De Luc as given in the 1827 ed., p. 506–508]; but the Daltonian theory of diffusion does. On the borders of the Orinoco, and during the rainy season, the (*Page* 228) clouds at first form and the rain is discharged only during the hottest hours of the day, and disappear at night. But as the season advances, and especially during the time that the sun is in the zenith, both commence in the morning. Towards the end of the wet season they are again confined to the afternoon. It would appear that these violent rains, so evidently connected with the rising temperature, as well as those which occur in the region of calms upon the broad oceans, depend upon the rising columns of rarefied air, which carry up with them in their ascent the highly elastic vapour of the hot latitudes. As they rise, the air assumes the equivalent temperature due to the elevations to which it ascends, which, falling rapidly below the constituent temperature

of the entangled steam, precipitates the excess in rain. The moisture is thus returned nearly to the surface from which it rises. The rain in extratropical regions gradually loses its periodical character, and the maximum quantity no longer falls when the sun is in the zenith, but rather in the winter months, when its influence is least, or on the decline. It proceeds principally from the vapour transported by the horizontal currents of the atmosphere, fed by the evaporation of the subjacent surface. In the temperate (*Page* 229) climates, however, the quantity of vapour in the atmosphere in the different seasons of the year (measured on the surface of the earth and near the level of the sea) follows the progress of the mean temperature. The elasticity of the aqueous atmosphere (*Page* 231) in the temperate zones, on the surface of the earth, separated from that of the aerial, generally exhibits directly opposite changes to the latter. Whenever the (*Page* 237) particles in the form of cloud, or fog, or condensing steam, are brought into contact with one another with mechanical force, as when they are carried by the wind (*Page* 238) against any obstacle, as a tree, a rock, or a building, they generally coalesce, become too heavy to be buoyed up by the air, and commence a rapid descent in the form of rain. This is an observation which any one may make who will attend to the phenomena of those dripping fogs with which our climate is sometimes infested [Hobbes in 1682 has somewhat the same idea]. Dove thus explains the cause of the horary oscil- (*Page* 298) lations of the barometer. The pressure of the atmosphere on the barometer being the sum of the pressure of the dry air and the vapour of water, the barometric column is, so to speak, of two parts: one corresponding to the air, the other to the vapour. Now when the temperature rises, the density of the air diminishes, but the tension of the vapour increases; and it is not easy to determine the relations which exist between the diurnal variations of the barometer and thermometer by taking account of each of these two influences. To obtain this, Dove analyzed the observations made by Neuber at Apenrade, with one of Daniell's hygrometers, and having calculated the tension of vapour for each hour of the day, subtracted it from the barometric column. (*Page* 299) He imagined that he thus obtained the pressure of the dry air alone, and of which there was but one maximum and one minimum; the former occurring about 1 A.M., and the latter about 2 P.M. These he ascribes to the diurnal variations of temperature with the maximum and minimum of which they are nearly coincident. This single maximum and minimum are also augmented by the vapour of water that rises during the day. In the morning, when the pressure of the dry air diminishes, not only does the tension of the vapour compensate this effect, but it makes the column rise; and it attains its maximum when the pressure of the air begins to diminish. For the same reason we find a minimum in the morning, because the diminution of the vapour during the night is more rapid than the increase of the pressure of the dry air (Kämtz, Martin's translation). Now we have already shown that the total pressure of the atmosphere of vapour upon the barometric column cannot be estimated by the tension of the lower stratum, and that the deduction of its amount from the height of the mercurial column will not afford us the amount of the dry air. The law of the progression of the elasticity of vapour mixed with an atmosphere of gas must be totally different from that of the gas itself; and we have shown there is reason to suppose that it is interstratified in beds of different degrees of force, each of which, in the act of diffusion, adds its different quota to the general pressure. Moreover, the results which (*Page* 300) have been derived by Dove from one year's observations at Apenrade are not confirmed by observations made at other stations, and indeed, are directly opposed to them. Observations between the tropics, where the variations of the dew point are the smallest, and the amplitude of the horary oscillations the greatest, are wholly inconsistent with this view.

Vol. II. 1845.

(*Page* 1.) 'Liquentia' [not linquentia as in 1823 edition, p. 139.]

(*Page* 15.) 'Physical' [not chemical, as in 1823 edition, p. 152.]

(*Page* 28.) '3.87 and 8.04' [in place of 3.37 and 8.01 in 1823 edition, p. 164.]

(*Page* 42.) [The table given at pp. 178–180, of the 1823 edition is modified in the 1827 edition, as shown in the notes under that year. In this edition, it is nearly the same as in that of 1827; the alterations are indicated below. In col. 2, opposite 20° — .02500 is given in place of — .02475.

(*Page* 43.) In 5th column we have

65	.9295
66	.9275
67	.9255

for the readings in the place where the copy of the 1827 edition was defective.]

(*Page* 45.) The calculations on p. 181 of the 1823 and 1827 editions run thus in this edition.] In the third column opposite to 40° we have .00942; and beside it in the fourth, .00580. Now .00942 — .00580 = .00362; which, subtracted from .94167 leaves .93805 as the number sought.

(*Page* 92.) Mason's form of dry and wet bulb thermometer is the most convenient kind of hygrometer. Dr. Apjohn gives the circumstances under which observations (*Page* 93) should be made. When in the moist bulb hygrometer the stationary heat is attained, the heat which vapourizes the water is assumed to be necessarily equal to that which the air imparts in descending from the temperature of the atmosphere to that of the moistened bulb. It is also assumed that the air which has undergone this reduction becomes saturated with moisture. In calculating from these assumptions (*Page* 94) the weight of water which would be converted into vapour by the heat which a given weight of air would evolve in cooling from the temperature of the air to that of the moistened bulb, it is not only necessary to know the tension of vapour for every degree of the thermometer within the atmospheric range, but the specific heat of air must be taken into account as well as the latent heat of steam. In the formula the latent heat of steam is assumed to be 1129°, and the differences of the specific heats under a constant volume are assumed to be proportional to the differences of pressure. Allow that these are sufficient approximations, there still remains an objection. It might be that when the stationary temperature has been reached, the quantities of heat which it loses and gains in a given time, are perfectly equal, and that the heat lost is entirely employed in converting the water into vapour, but the whole of the acquired heat is not necessarily derived, though this is assumed to be the case, from the air (*Page* 95) cooled by contact with the bulb of the instrument. In fact, the hygrometer is in the predicament of a cool body placed in a warm medium, and it must consequently receive from surrounding bodies a greater amount of heat than it imparts to them in virtue of the same process, and this will even vary with the state and colour of its surface. Dr. Apjohn acknowledges that this disregarded influence must be of sufficient magnitude to exert an appreciable influence, and regrets his inability to assign any means of determining its amount. The scale is too small; the readings should be made to one-tenths of a degree Fahr. The probable errors of observation bear a high proportion to the required result, particularly about 32°. An error in reading of $\frac{1}{2}$° at 32° would affect the observation with an error of $\frac{1}{35}$th of the whole amount; at 80° the inaccuracy would amount to about $\frac{1}{300}$th. But there is a still more serious source of error, if Peltier is to be trusted. He has shown that from a surface charged with resinous (*Page* 96) electricity, the process of evaporation in the atmosphere is more rapid than from the same surface in a neutral state. If this is the case, then the hypothesis that such process is wholly dependent upon calorific influence must lead to erroneous results; and it is not at all improbable that in some such unappreciated influence the explanation

will be found of those negative results, in which the temperature of the wet thermometer has been found above that of the dry, which occur in all long series of observations, and which have been ascertained with the greatest care in the Greenwich observations. The formula for the calculation of the elasticity of steam from the observation of the moist bulb thermometer, as finally corrected by Dr. Apjohn, is as follows: $f'' = f' - \frac{d}{88} \times \frac{p}{30}$

wherein f'' denotes the tension of steam at the dew point; f', the tension of steam at the observed temperature of the air; d = the depression of the moist surface; 88 (or possibly 87) = a co-efficient dependent upon the specific heat of the air and the latent heat of the vapour; p = the existing pressure of the air; 30 = the mean pressure of the air. Dr. Apjohn has, moreover, calculated the subjoined table (Phil. Mag. 1835, vol. VII.) (*Page* 97) by which the determination of the dew point from the formula is greatly facilitated. It gives $\frac{d}{87 \times 30}$ for every value of d between .1 and 10. In calculating an observation this quotient, as is obvious from the formula, is to be multiplied by p the existing pressure, and the product when deducted from f' will afford f''. Should the depression exceed 10° the value of $\frac{d}{87 \times 30}$ may still be derived from the table by addition. Thus if $d = 13°$ $\frac{d}{87 \times 30} = .00383 + .0014 = .00497$. The following is the table. The first column is d; the second $\frac{d}{87 \times 30}$.

.1	.00003	3.5	.00134	6.8	.00260
.2	.00007	3.6	.00137	6.9	.00264
.3	.00011	3.7	.00141	7.0	.00268
.4	.00015	3.8	.00145	7.1	.00271
.5	.00019	3.9	.00149	7.2	.00275
.6	.00022	4.0	.00153	7.3	.00279
.7	.00026	4.1	.00157	7.4	.00283
.8	.00030	4.2	.00160	7.5	.00287
.9	.00034	4.3	.00164	7.6	.00291
1.0	.00038	4.4	.00168	7.7	.00294
1.1	.00042	4.5	.00172	7.8	.00298
1.2	.00045	4.6	.00176	7.9	.00302
1.3	.00049	4.7	.00180	8.0	.00306
1.4	.00053	4.8	.00183	8.1	.00310
1.5	.00057	4.9	.00187	8.2	.00313
1.6	.00061	5.0	.00191	8.3	.00317
1.7	.00065	5.1	.00195	8.4	.00321
1.8	.00068	5.2	.00199	8.5	.00325
1.9	.00072	5.3	.00202	8.6	.00329
2.0	.00076	5.4	.00206	8.7	.00333
2.1	.00080	5.5	.00210	8.8	.00337
2.2	.00084	5.6	.00214	8.9	.00340
2.3	.00087	5.7	.00218	9.0	.00344
2.4	.00091	5.8	.00222	9.1	.00348
2.5	.00095	5.9	.00225	9.2	.00352
2.6	.00099	6.0	.00229	9.3	.00356
2.7	.00103	6.1	.00233	9.4	.00360
2.8	.00107	6.2	.00237	9.5	.00363
2.9	.00111	6.3	.00241	9.6	.00367
3.0	.00114	6.4	.00245	9.7	.00371
3.1	.00118	6.5	.00248	9.8	.00375
3.2	.00122	6.6	.00252	9.9	.00379
3.3	.00126	6.7	.00256	10.0	.00383
3.4	.00130				

(*Page* 98.) When the reading, however, of the wet thermometer is lower than 32° the formula becomes $f'' = f - \frac{d}{96} + \frac{p}{30}$ because the latent heat of water as well as the

latent heat of steam must be taken into account, as the heat evolved has first to liquefy ice and then to convert the water into vapour. These calculations are troublesome, and some of the data are uncertain. It rarely happens that any one will make them for a long series of observations. Without reduction no precise conclusions can be obtained. (*Page* 99) Observations of the dew point by hygrometer has already led to most valuable conclusions. The safest deductions from the differences between the dry and wet bulb thermometers are those which may be derived from a long series of experimental comparisons with the differences between the dew point and the temperature of the air, which, as bearing a fixed ratio to each other, may probably be depended upon, at least in the locality in which the observations were made. The Astronomer Royal has thus constructed from the Greenwich observations a table of the values of the fraction:

$$\frac{\text{Difference between dew point and temp. of air.}}{\text{Diff. between evaporation temp. and air temp.}}$$

The difference between the dry and wet thermometers multiplied by these factors according to temperature and deducted from the temperature of the air, will give a close approximation to the dew point. Suppose the observation to have been

Air.		Evap.		Diff.	Factor.
51.5	–	46.7	=	4.8	4.8 × 2 = 9.6

51.5 – 9.6 = 41.9 dew point.

(*Page* 100.) Greenwich factors for finding dew point from temperature of evaporation.

Temp. of air between		Temp. of air between	
20–25°	9.0	55–60°	1.7
25–30	5.2	60–65	1.7
30–32	4.1	65–70	1.6
32–35	2.8	70–75	1.5
35–40	2.5	75–80	1.5
40–45	2.2	80–85	1.6
50–55	2.0	85–90	1.7

From a comparison of two years' observations at Greenwich of the wet bulb hygrometer with those of the dew point hygrometer it appears that the extreme differences are by Dr. Apjohn's formula

–3.9 between 65° and 70°
+3.6 „ 75 „ 80

whilst the extreme differences by the Greenwich factors are

–3.7 between 75° and 80°
+5.6 „ 75 „ 80

Thus an appeal must be made to the dew point hygrometer whilst we are seeking to become acquainted with the almost infinitely varying circumstances by which the evaporation hygrometer is affected. [Table XXXVI is placed opposite p. 115 in the Meteor. Soc. copy. It should be in vol. I. opp. p. 115.]

(*Page* 154.) [He gives directions for observing with actinometer. He says perfect clearness of sky is indispensable, the slightest cloud or haze over the sun being at once marked by a diminution of resulting radiation. To detect such haze or cirrus a brown glass applied before the eye is useful. He gives Forbes's actinometric observations at (*Page* 165) Brienz and Faulhorn; these are local, but the following comments are made which bear upon aqueous vapour.] With respect to the points of contrary flexure, they probably arise from a twofold effect of the sun's radiation. The one is the increased intensity as the sun is higher; the other is the transference of vapour from the lower to the higher regions of the air by the heating of the lower strata producing incipient condensation at a certain elevation and slight clouds which often appear between 10 and 12 o'clock. As the sun's power diminishes and the vapours redescend into the less rarefied and warmer regions, they are in some degree redissolved in the afternoon, and the increased

transparency of the atmosphere checks the downward progress of the curve due to the increasing obliquity of the rays. The maximum of intensity is sooner attained above than below because the sun shines with a disproportionate intensity in the morning on the upper station owing to the mass of vapour being then in the valleys. Forbes asks (*Page* 166) what becomes of the heat absorbed by the air. Is it radiated in rays of a different order from the clouds ? or is it rendered latent by the conversion of the latter into vapour ?

(*Page* 219.) 1000 [for 1.000 in 1827 edition, p. 513].

(*Page* 385.) The periodical increase and decrease of intensity [of atmospheric electricity] is so regular as evidently to be connected with the position of the sun above or below the horizon, and is probably directly dependent upon the ultimate tendencies to precipitation and evaporation produced by the regular changes communicated to the air. It should also be remembered that similar and contemporaneous changes seem to affect the magnetic phenomena of the earth. With regard to the sources from whence the air (*Page* 387) receives its electric charges, we are in a state of great ignorance. Up to the time of the late experiments of Dr. Faraday upon the electricity of effluent steam, little doubt was entertained that the processes of evaporation and condensation were the most active in supply.

Hunt, Carew. *Journ. Roy. Geog. Soc.*, vol. xv. (1845.) (*rv.*)

(*Page* 284.) On the Island of St. Michael the mean hygrometrical dew point of the summer half-year has been 58½°; of the winter, 55°; making the quantity of vapour in a cubic foot of air 5.35 grains and 4.87 grains. Either in consequence of this humidity or the conducting power of the mountains, heavy thunderstorms are unknown. The (*Page* 285) evaporation of the summer months is 28 inches, and of the winter 17 inches.

1846.

Journ. Roy. Geog. Soc., vol. xvi. (1846.) (*rv.*)

[Nothing in it for these notes.]

1847.

Journ. Roy. Geog. Soc., vol. xvii. (1847.) (*rv.*)

[Nothing for these notes.]

1848.

Barker, Lieut. *Journ. Roy. Geog. Soc.*, vol. xviii. (1848.) (*rv.*)

(*Page* 132.) Along the E. coast of Africa, from Goobul Karab to Core Kurangwah, October to April is the rainy season [and hence the dry season occurs during the other part of the year].

1849.

Cruttenden, C. J. *Journ. Roy. Geog. Soc.*, vol. xix. (1849.) (*rvp.*)

(*Page* 69.) [When high upon the Peak of Eyramid in the Somali country he refers to the night being bitterly cold, 48°, and the dew falling like soft rain.]

Norton, W. A. (*B.* 1849, 3.)

(*Page* 352.) [He attributes the decrease in the horizontal force of the magnetic needle from 4 A.M. to 6 A.M. to evaporation, a supposition which implies that evaporation is greatest at these hours. He says this is the case. For the dew deposited at night is evaporated during the morning hours; and the greater part of the evaporation of the rain that falls during the night and the latter part of the day will take place during the forenoon of the following day, except when the ground is unusually moist, in which case the evaporation will be most energetic during the warmest part of the day.]

1851.

Fitz Roy, R. *Journ. Roy. Geog. Soc.*, vol. xx. (1851.) (*rvp.*)

(*Page* 107.) In Central America hot and dry weather prevails in the summer season when the sun is not so high at noon as in winter. In the northern parts of the Isthmus the dry season lasts longer than about Darien and Choco. In the season called winter the sun is seldom seen, so clouded is the sky. There is a short interval of fine weather in the middle of the rainy season near the end of June, but the regular and continued summer, a very dry and parching time in the northern parts of the Isthmus, lasts from December to April or May.

Gutzlaff, Ch. *Journ. Roy. Geog. Soc.*, vol. xx. (1851.) (*rvp.*)

(*Page* 200.) In Tibet from October to March the sky is clear, the atmosphere is arid, and the vegetation is frequently scorched by dry winds.

Livingston, Dr. David. *Journ. Roy. Geog. Soc.*, vol. xx. (1851.) (*rvp.*)

(*Page* 140.) The dry season on the Zouga extends from May to October.

Parkyns, Mansfield. *Journ. Roy. Geog. Soc.*, vol. xx. (1851.)

(*Page* 261.) In the region occupied by the Kubbabish Arabs between Kordofan and Dongola there is a dry season before the rains (about April and May).

Wallin, G. A. *Journ. Roy. Geog. Soc.*, vol. xx. (1851.) (*rvp.*)

(*Page* 299.) At Muweilah, and to some extent throughout the N.E. part of Arabia, rain falls at intervals from October to April. During the remaining months the weather is hot and dry.

Journ. Roy. Geog. Soc., vol. xxi. (1851.) (*rv.*)

[Nothing in it for these notes.]

1852.

Journ. Roy. Geog. Soc., vol. xxii. (1852.) (*rv.*)

[Nothing for these notes.]

1853.

Davis, Sir J. F. *Journ. Roy. Geog. Soc.*, vol. xxiii. (1853.) (*rvp.*)

(*Page* 247.) The wet and dry seasons at Chusan and at Hongkong are reversed; in the south the winter is dry, and the flooding rains fall during summer.

Findlay, A. G. *Journ. Roy. Geog. Soc.*, vol. xxiii. (1853.) (*rvp.*)

(*Page* 237.) Beyond the tropics the warm wind descends and blows towards the poles, parting with its heat and moisture; till at last reaching the pole quite dried, and at a minimum temperature, it by its accumulation rises and returns to the tropics. If the earth's surface were uniform, these belts of calms and winds would be symmetrical on either side of the equator. But the proportion of land to water in the northern hemisphere is 100 to 154; while in the southern hemisphere it is 100 to 628, according to Prof. Renouard. Yet all the countries in S. latitude are remarkable for the dryness of their climate, and it can be demonstrated that the evaporation of the southern is deposited in the northern hemisphere. From this unequal distribution of land and its (*Page* 238) effects we have the phenomenon of that line of junction of the trade winds to the north of the equator (in a mean between 8° and 2° N. lat.) varying with the progress of the sun in the ecliptic, but always characterized in its axis by an enormous deposition of rain.

Strachey, H. *Journ. Roy. Geog. Soc.*, vol. xxiii. (1853.) (*rvp.*

(*Page* 64.) In the high Tibetan regions, as elsewhere, wind and moisture seem to be connected with low barometer. Winter is the season of clouds at Ladak, the number (*Page* 65) of cloudy days exceeding the fine ones; in spring they are nearly equal; in summer the sunny weather greatly exceeds the cloudy; and in autumn the sunshine still predominates in a less degree. The snow line of a country may be regarded as (*Page* 68) an index of its joint thermometric and hygrometric status and their mutual reaction. The hygrometric element has often been too much overlooked.

Sykes, W. H. *Journ. Roy. Geog. Soc.*, vol. xxiii. (1853.) (*rvp.*)

(*Page* 111.) At Zanzibar, from observations made by Lieut. Fergusson in 1850, the mean depression was 22° [=2.2°], and the mean dew-point temperature by Glaisher's factors 76.6°; by Apjohn's formula 76.85°. The lowest dew point was 72.9°, and the highest (*Page* 113) 79.3° in April. The sky seems ever clouded. The place is remarkable for the extraordinarily continuous amount of humidity and the consequent very high tension of vapour, humidity so great that in the driest month, February, it amounted to 87; while in every other month of the year it was never less than 91 per cent. Nothing approaching to these facts occurs on the shores of India; even during the monsoons. At Bombay the highest percentage of humidity was 88 in July, and the mean of the year 66 in 1844. At Madras in the same year 83 per cent. in December (a monsoon month), and the mean of the year 74½ per cent. At Calcutta in 1844 in August the percentage was 94, and the mean of the year 84. At Aden in Arabia in 1848 the highest percentage was 77½, and the mean of the year 71 per cent. In the tablelands of India the mean annual percentage of humidity ranges from 55 to 60. In India the only approach to the humidity of Zanzibar is met with in the cloud-capped summit of Dodabetta, at 8640 feet above the sea; in Oct. 1847 (a monsoon month) it amounted to 97 per cent., and the mean of the year was 90 per cent. From various short observa-(*Page* 114) tions made by Capt. Elliott, the atmosphere of Zanzibar would seem to be more continuously loaded with vapour than any place to the eastward. It does not necessarily follow that the highest temperature of the air and the highest temperature of evaporation give the highest dew point and consequent tension of vapour. Witness Batavia and Moulmein; at the former the temperature of the air and evaporation was 85.8° and 79.4°, and at the latter 100.9° and 83·3°, yet the tension of vapour and dew point were identical at both places, viz. .909, and dew point 76.95°, while at neither place (*Page* 115) was the degree of humidity equal to that of Zanzibar.

EXPLANATORY REMARKS.—II.

It is no part of the plan of the 'Scientific Roll' to correct and comment upon the views and statements of the various authors. If such a course were adopted the spirit of impartiality which it is hoped will be adhered to in the "Notes" would not be maintained. Each author is allowed to state his own views, and each reader must judge for himself which views are the more correct by a careful comparison of one with the other. In many cases the errors of one writer are pointed out by subsequent writers. Moreover, if comments were made upon the "Notes" whenever they seemed to be called for, the work would be extended to a most inconvenient size, as the comments would be more voluminous than the "Notes" themselves. Hence it is necessary for the reader to thoroughly criticize all the notes before accepting their strict accuracy as matters of fact. The Conductor does not claim to write with any high authority, but is simply endeavouring to carry out what he conceives to be a useful plan to the best of his power. In order to ascertain what writers mean, and how far they agree or disagree, it is necessary to make comments, which are kept with the "Notes" in the manuscript

state, but are not intended for publication. As a sample of these we give those referring to the Rev. Edward Saul's Notes under the year 1766.

Saul clearly perceives that vapour adds to the weight of the air, but he does not see that owing to its unequal diffusion the specific gravity of the air is least in the place where there is most vapour. He believes that as the variation in the barometer indicates a greater variation of weight than is consistent with the addition and withdrawal of the probable amount of vapour in the air, therefore such variation cannot be due to vapour. His mistake lies partly in overlooking the question of specific gravity, and partly in ignoring that the vapour may have some influence on the result. Suppose the pressure over all the earth to be 30 in., then the uniform addition of vapour corresponding to .025 in. of mercury would increase the pressure to 30.025 in. Suppose, however, that the addition is confined to one hemisphere, then the air in the moister hemisphere would expand, and cause a compression of the air in the drier hemisphere to such an extent that the mean pressure of the two hemispheres would be 30.0125. If, then, the effect was to lower the pressure in the moist hemisphere to a mean of 29.990 in., it would raise that in the other to a mean of 30.035 in. In fact, the increased pressure would manifest itself in the dry regions, not in the moist. Therefore the diffusion of vapour will cause variation of pressure, increasing it in the dry regions just as much as it decreases it in the moist. The mean pressure will vary with the quantity of vapour, and the mean variation also will vary with the quantity of vapour. The difference of pressure in contiguous areas will increase with the quantity of vapour. The precise extent of the influence of vapour requires to be accurately gauged. It is only one of several causes which influence pressure. It is not (*Page* 16) quite clear what Saul intends to impute to Boyle. The meaning which the passage bears implies that the cloudiest days are always those on which the barometer is lowest. If this were strictly true, then the range of the barometer below a certain maximum would be a gauge of the degree of cloudiness. Is this so? Again, it also implies that the barometer is lowest on days which have the most vapour in the air, quite irrespective of cloudiness. In this case the barometer should rise and fall inversely with the dew point, being highest when it is lowest; and axiomatically the height of the barometer should be correlative with the dew point. The latter idea is in effect rejected by him (on *Page* 26), because the range of the barometer indicates a greater quantity of vapour in the air than is credible, viz. 42 in. of water for England. By parity of reason, the barometric range of the equator would imply a far less amount, which is not consistent with well-established facts. The case of high barometer in fogs is in opposition to Boyle's idea; and the fall of the barometer at times with rise of fogs, also seems to be against it. Boyle's view may be right in the sense that the pressure is *relatively* least where most vapour is. The meaning implied by Saul seems, however, to be *absolutely* least.

Boyle's idea of the connection between cloudiness and low barometer may be tested by arranging cloudiness, the pressure of vapour, and the humidity, according to quantity, and setting against them the contemporaneous barometric height. Then the barometric heights may be arranged in the order of height, and the cloudiness set against them. The observations made by Professor Kedzie at Lansing, in Michigan, will be used for the purpose of testing this point.

First, then, take cloudiness.

Date, 1878.	Observation hour.	Percentage of sky covered.	Height of barometer. inches.
Jan. 1.	7 a.m.	100 cum.-stratus.	28.963
	2 p.m.	do.	28.890
	9 p.m.	do.	28.912
„ 2.	7 a.m.	100 nimbus.	29.123
„ 4.	7 a.m.	do.	28.839
	2 p.m.	do.	28.863

Date, 1878.	Observation hour.	Percentage of sky covered.	Height of barometer. inches.
Jan. 5.	7 a.m.	100 stratus.	29.196
	2 p.m.	100 nimbus.	29.055
„ 7.	7 a.m.	100 stratus.	29.511
	2 p.m.	do.	29.513
	9 p.m.	do.	29.454
„ 8.	7 a.m.	100 nimbus.	29.286
	2 p.m.	100 stratus.	29.215
	9 p.m.	do.	29.237
„ 9.	7 a.m.	do.	29.193
	2 p.m.	do.	29.056
	9 p.m.	do.	28.955
„ 2.	9 p.m.	No cloud.	29.259
„ 3.	7 a.m.	do.	29.267
„ 5.	9 p.m.	do.	29.015
„ 6.	9 p.m.	do.	29.356
„ 23.	7 a.m.	do.	29.431
Feb. 10.	9 p.m.	do.	28.912

Next take the pressure of vapour. The first group are observations with high-vapour pressure; the second those with low-vapour pressure.

Date.	Observation hour.	Vapour pressure.	Height of barometer.
Jan. 10.	9 p.m.	.188 in.	28.807 in.
„ 16.	7 a.m.	.188	28.895
„ 17.	2 p.m.	.212	28.987
„ 20.	7 a.m.	.229	28.936
	2 p.m.	.241	28.882
	9 p.m.	.204	28.929
„ 21.	7 a.m.	.188	28.950
	2 p.m.	.204	28.925
„ 25.	9 p.m.	.199	28.950
„ 2.	7 a.m.	.098	29.123
	9 p.m.	.065	29.259
„ 3.	7 a.m.	.071	29.267
	2 p.m.	.066	29.013
„ 4.	9 p.m.	.086	28.980
„ 5.	7 a.m.	.065	29.196
	2 p.m.	.075	29.055
	9 p.m.	.048	29.015
„ 6.	7 a.m.	.050	29.138
	2 p.m.	.086	29.189
	9 p.m.	.055	29.356
„ 7.	7 a.m.	.062	29.511
	2 p.m.	.055	29.513
	9 p.m.	.051	29.454
„ 8.	7 a.m.	.060	29.286
	2 p.m.	.087	29.215
„ 23.	7 a.m.	.065	29.431
	2 p.m.	.084	29.410
	9 p.m.	.082	29.443
„ 28.	7 a.m.	.082	29.137
	2 p.m.	.087	29.177
	9 a.m.	.071	29.237
„ 29.	7 a.m.	.057	29.343

There seems to be an inverse relationship here. Now test this quantitatively. On Jan. 10 and 16 the vapour pressure was .188 in.; on the former date the barometer was 28.807 in., and on the latter, 28.895. Although the vapour pressure is the same, the barometer has risen .088 in. What caused this difference? The humidity was the same on both occasions, or 100; the temperature was the same; and the cloudiness was the same, that is, 100. The wind on the 10th at 9 p.m. was N.W. 4, and on the

16th, at 7 a.m., S.W. 2. Would the wind cause it? or is it that the vapour observations are too local and rough? On the 21st, at 7 a.m., the vapour pressure was .188, and the barometer was 28.950 in.; the temperature was the same as before; the humidity 100; and the cloudiness 100. The wind was N.E. 4. On the 25th, at 9 p.m., the vapour pressure was .199 in., and the barometer 28.950 in.; that is, with more vapour the barometer was at the same height. On the 21st, at 2 p.m., the vapour pressure is .204 in., and the barometer 28.925. The vapour is .005 more, and the barometer is .025 less; this gives an *inverse* ratio of 1:5. On the 17th, at 2 p.m., the vapour is .008 in. more, and the barometer .058 in. higher, which gives a *direct* ratio of 1 to 7. There is, evidently, some great irregularity here, which should perhaps be eliminated if the vapour pressures were grouped. The following table results from doing this, and taking the mean height of the barometer coincident with them.

Vapour pressure.	Barometer pressure.
.040 – .050 in.	29.015 in.
.050 – .060	29.358
.060 – .070	29.282
.070 – .080	29.186
.080 – .090	29.266
.090 – .100	29.123
.200 – .210	28.934
.210 – .240	28.938

But the irregularity is still just as manifest, and further tests are required to make the matter clear. For instance what causes this great difference? On Jan. 6 at 7 a.m. the vapour pressure was .050 in.; and the barometer stood at 29.138 in.; while on the 7th at 9 p.m. the vapour pressure was .051 in., and the barometer indicated 29.454. The difference in the vapour pressure was +.001 in., and the difference in the barometric pressure was +.316. The facts seem to point to the conclusion that the data given are simply local-vapour tension, and that the true vapour pressure is a very different thing as pointed out by Daniell.

In order to test the statement on p. 26, it would be necessary to ascertain what have been the ranges of the barometer under special circumstances, and what amounts of aqueous vapour in the air have been associated with such ranges. Saul says nothing of temperature nor of wind, which ought to be taken into account. As this has most to do with barometric condition, the point is tested under that heading in various ways, with the result that Boyle's conclusions are not substantiated.

On p. 27 Saul refers to the vapour floating in the air as though he regarded the visible cloud as the sole representative of the vapour in the air, and therefore appears not to take into account the invisible vapour diffused in the air. In the sequel he makes some distinction between vapours and clouds, but seems to think that the less compact vapours are arranged in strata like the clouds.

On p. 29 he seems to regard the vapour as distinct from the air, and being lighter, it rises like a cork in water, and settles at that height where the air has the same specific gravity as itself. As the weight of the air is ascribed solely to the quantity of air, the heavier the air is the higher such vapour must rise. As the air varies in weight, the vapour will rise up and sink down. This is a simple view; but he ignores the property of the diffusion of gases. The exhalation of vapours by subterranean heat probably takes effect only in volcanoes and hot springs; and is not so general as he would seem to imply. If his ideas were right, the zone of maximum humidity should rise faster during periods of high than of low barometer. At what rate does it rise? Further, if his view is right, taking heavy to mean dense, then the height of clouds should on the average range with that of the mercury, that is, be higher in cold weather than in hot. This is not the case, as clouds are higher in summer than in winter. Saul gets rid of this difficulty by assuming that the vapours are of different specific gravities.

If we reduce Dr. Halley's estimate on p. 74 to some standard which should be generally adopted, we have the following results. It remains to be decided what standard shall be adopted. For the present one square mile will be tried. The area of the Mediterranean is 734,000 sq. miles, which would give 7193 tons, and 40,871 tons per square mile respectively; or 11 tons and 63 tons per acre; or .0043 in. of mercury and .0246 in. of mercury; or 15.1 grains and 86.5 grains pressure per square inch. The pressure in grains per square inch may be the best standard, more especially if the barometric pressure be expressed by weight, not by inches of mercury. How did Halley form his calculation and where? and what is the difference between the result indicated by his figures and the conclusion that might be drawn from observations on aqueous-vapour tension? For instance, in the quarter ending Dec. 31, 1881, the elastic force of vapour is given as .234 in. for Bolton and .372 in. for Osborne; which would give pressures of 853 grains and 1312 grains per square inch. The elastic force is of course a computed thing, and gives no clue to the amount of vapour over any given spot. Books seem to imply that the aqueous-vapour pressure is indicated by this elastic force. It seems rather to indicate the local amount of vapour in the area immediately about the point of observation. The actual pressure is a very much smaller figure as indicated by Halley, as also by Daniell. Much of this really appertains to barometric pressure, but the question requires discussion here in order to ascertain what is the probable amount of vapour in the air per square inch, or per acre, or per square mile. With an elastic force of .234 in. there were 2.7 grains in each cubic foot of air. A cubic inch would contain .0015 grain; and on the assumption of uniform distribution, this would give an aqueous-vapour column of nearly 9 miles. A cubic inch of rain would weigh about 252 grains, so that it would correspond to an elastic force of .069 in. Returning to Halley's estimate, it may be observed that the greatest pressure is 86.5 grains on the square inch, or .0246 in. of mercury, while the total pressure would be about 30 in. The ratio of the vapour to the air would be as 1 to 1215. Hence it would be inferred that vapour *per se* has little influence in varying the pressure. The main effect would, then, probably be caused by heat and liberation of latent heat diminishing the specific gravity of the column owing to overflow or passage of the air into neighbouring regions as pointed out by Daniell. Hence, then, it will seem probable that the main factor in the variation of the barometric condition is the latent heat liberated by condensing vapour. The barometer may consequently give a rough indication of the amount of heat liberated, and hence indirectly of the quantity of vapour condensed. The difference in the height of the barometer may be mainly due to the difference in the specific gravity of the air, one important factor in regulating which difference is the unequal diffusion caused by heat and evaporation, and the consequent unequal condensation of such vapour giving rise to evolution of heat derived from places of higher temperature. If so, then it will be seen how intimately connected are the climatal elements, aqueous vapour, barometric condition, temperature and wind.

Scientific Union.

The rapid progress of science now going on is, in part, the result of the great increase in the number of workers. This is accompanied by a larger and larger host of scientific serials. The consequence is that the student finds an increasing difficulty in ascertaining what has been done, or is in process of being accomplished, not only in his own special line of study, but also, and more particularly, in such as do not immediately interest him. Every student finds, from time to time, that he has a desire for full information on subjects in these outlying sciences, for the purpose of throwing light upon his special studies. The state of literature is such that he is frequently daunted by the difficulties attending his research, or, if he perseveres, he finds a great deal of time unnecessarily wasted. The remedy for this is the focalisation of knowledge round a series of centres. The two main steps in the process are, first, collection, and, next, classification. It is with this ulterior object in view, that all persons interested in meteorology are earnestly asked to forward their names and addresses, particulars as to the work they have done in meteorological and other sciences, their present lines of study, ways in which help is desired, and any other items that may occur to them. These details will be classified, and, when the opportunity offers, selections from them will be published. The Conductor will exercise careful discretion in the selection, as also in the use he may make of the more private details. The first list will be published in November, 1883; but correspondents are requested to send in answers soon, in order to allow of ample time for their classification, and for their utilisation in private correspondence in the interests of correspondents.

In order to prevent any misconception, it may be stated that the Conductor's object is solely to promote scientific union, and is no way intended to be of a charitable nature in any pecuniary sense. If there is a sufficient response to these requests, the same line of proceeding will hereafter be suggested, from time to time, for the students in other branches of science.

Newspapers and scientific journals of all countries, willing to help in this matter, are asked to make the above requests known to their readers.

Address, Conductor, 'Scientific Roll' office, 7 Red Lion Court, Fleet Street, London, E.C.

The above notice first appeared in August, 1882, and has been repeated in the subsequent numbers. As yet not a single individual has complied with the request made. It is only from individuals that reliable materials can be obtained; consequently, if no response is made, no list of the kind proposed will be attempted.

The members of the British Association Committee for drawing up suggestions upon

methods of more systematic observation, and plans of operation for local societies, have been appointed. It is to be hoped that the magnificent results obtained by the United States Fish Commission, by the Electrical Conference at Paris, by the United States National Board of Health with respect to water analysis, and other subjects, and by other bodies which have seen the importance of a systematic plan of operations, will encourage our local societies to combine cordially and unanimously in prosecuting some well-organized plan for the investigation of some definite subject. There are many subjects which might be taken up in this way, and there are many branches of industry and art which do not receive adequate systematic investigation, because those who practise them for profit will not give the time and care necessary for the purpose. There is no doubt practical men would derive great advantage from well-organized systematic observations, and it is to be regretted that so few have been made. The valuable and long-continued work of Drs. Lawes and Gilbert, of Rothamsted, has induced a spirited American gentleman, Mr. Lawson Valentine, to acquire a farm for the purpose of carrying out a system of agricultural experiments. His present plans, he states, are: "First, that the farming operations be carried on in accordance with the best-known methods, and under the best possible organization and management, with a view of educating and enlightening others by furnishing valuable examples and results in practical agriculture. Second, that there be a scientific department devoted to agricultural investigation and experiment, and that such department be of the highest order so as to command the respect, interest and co-operation of the leading scientific minds of this and other countries. Third, that Houghton Farm be a comfortable, healthful and attractive home for the family of its proprietor, and afford large hospitality for friends and guests." If a dozen establishments of this kind were started in various parts of the world, it would not be long before agriculturists reaped benefits which in the ordinary way of farming would not be acquired for centuries. In the preliminary report which the present director of the experiments, Mr. Penhallow, has kindly sent us, we have an account of the experiments on Indian corn carried on by Mr. Manley Miles during 1880 and 1881. We do not propose to analyze those results, but we would quote a passage indicating the spirit in which enquiries will be made:—"Two distinct although closely related and parallel lines of investigation are needed to furnish that accurate knowledge of natural laws that is best adapted to the wants of the practical farmer. In the first place, we must leave the purely scientific work of the laboratory to gain a knowledge of the elements of animal and vegetable nutrition and of their relations under known definite conditions; and investigations in this direction may with advantage be very much extended. The most obscure fact in organic chemistry, that has no apparent relation to the practical affairs of life, is of great value; and when its bearings are fully appreciated it may be found to have an influence on matters of every-day interest. In this utilitarian age, when the so-called practical side of affairs is kept prominently in view and industrial education is so generally demanded, there is danger that the importance of pure science, which furnishes the means of exact investigation in matters pertaining to practical ends, may be overlooked, and opportunities for extending its domain by original research neglected.

"In the second place, accurate and well-planned experiments in the feeding of animals, and with crops in the field, are needed to answer the various practical questions that arise in the management of the farm, and to determine the agricultural value of the facts and theories that are presented as the result of purely scientific investigations. Experiments under this second head, without departing too widely from established methods of farm practice, must be conducted in accordance with strictly scientific methods, notice being taken of every condition that may possibly influence results; and they demand on the part of those who conduct them an extended knowledge of practical farming, and the trained skill and ability for original investigations that are required in researches in pure science."

In 1882 the present director of experiments commenced a series of methodical investigation into the causes of the disease called "yellows" in peaches. As this investigation is still in progress, and as many horticulturists both in the United States and elsewhere may be willing and able to co-operate, the questions issued by Mr. Penhallow are reprinted here.

The Scientific Enquirer.

Correspondence is invited on Science matters of all kinds. In all cases names and addresses should be given; but these will not be published without the writer's consent. The Conductor will not be responsible for the opinions expressed by correspondents. All communications should be addressed to the Conductor, 7, Red Lion Court, Fleet Street, London, E.C.

Replies to questions should be numbered in accordance with the questions to which they refer. The contractions following the questions and answers, indicate the class of notes to which they will ultimately be assigned, and the place where full reference will be given to the details bearing upon them. The following request and set of questions are reprinted from the circulars sent us by Mr. Penhallow. The numbers in parentheses are those given in the original, those which precede them are those adopted for the 'Scientific Roll' for the purpose of reference.

P=Plantae.

Experiments and observations are now being made at the Houghton Farm Experiment Station, upon the diseases of fruits, with a view to determining their cause and the remedies which may be applied. To make our work of the greatest practical value, it is earnestly desired that fruit growers and Horticultural Societies will lend us their aid, and those whom these circulars—with their accompanying forms—may reach, will confer a favour by making careful observations upon their trees according to the following questions; and at the end of the growing season—when the fruit is ripe—fill in the answers and return to Houghton Farm. Any information concerning the disease in past years will be of great value. Those who feel an interest in this work and desire to avail themselves of what is already known concerning the treatment of Peach Yellows and Pear Blight, will be furnished with printed directions upon application.

Address,

D. P. Penhallow,
Botanist to Houghton Farm Experiment Station,
Mountainville, Orange Co.,
New York, U.S.A.

QUESTIONS RELATING TO THE PEACH TREE AND THE DISEASE CALLED "YELLOWS."

Please observe carefully, fill in your answers concisely, and return as soon as the fruit ripens.

Make careful distinction between Blight and Yellows.

151. (1.) At what time of year does the disease first appear? (P. 1)

152. (2.) Does the disease first appear before or after the tree has come into bearing, or is that a matter of indifference? Which is the more common? (P. 2)

153. (3.) Which is the more liable to attack, seedlings or grafted trees? Is there any difference? (P. 3)

154. (4.) What is the first indication of disease in an apparently healthy tree? (P. 4)

155. (5.) Where does it first appear? (P. 5)

156. (6.) Is the disease localized, *i.e.*, confined to particular parts of the tree, or is the whole tree gradually involved? (P. 6)

157. (7.) When a tree is attacked, how long before it dies? (P. 7)

158. (8.) Is there any difference in the health of trees on account of location, as between high land and low, or on account of different exposure? (P. 8)

159. (9.) How old are your trees? (P. 9)

160. (10.) How long has the disease run? (P. 10)

161. (11.) What manures have been applied? (P. 11)

162. (12.) Has there been any apparent effect? (P. 12)
163. (13.) What has been your method of treating diseased trees? (P. 13)
164. (14.) What has been the result? (P. 14)
165. (15.) How is the fruit affected when it forms before disease is evident? (P. 15)
166. (16.) How is the fruit affected when it forms on the diseased tree? (P. 16)
167. (17.) How long has the disease been known in your locality? (P. 17)
168. (18.) What has been the effect upon the annual yield of fruit? (P. 18)
169. (19.) How long have you cultivated the peach? (P. 19)
170. (20.) Has the disease increased or decreased during that time? (P. 20)
171. (21.) How many diseased trees have you? (P. 21)
172. (22.) How many healthy trees have you? (P. 22)
173. (23.) What is the yield in bushels, for this year, of the healthy trees? (P. 23)

ANNOUNCEMENTS.

Part III. of the 'Scientific Roll' will be commenced, if life and health and support be granted to the Conductor, in November 1883. In order that the Bibliography may be as full as possible, authors and publishers are respectfully solicited to send copies of, or references to, all their publications dealing with the barometrical condition of the air.

As soon as 200 persons have expressed a wish to subscribe for any one of the subjects mentioned below, the publication of that section of the 'Scientific Roll' will be forthwith commenced. The subscription price will be 7*s.* 6*d.* and 10*s.* for each volume, according as the residence of the subscriber is at home or abroad. Each volume will comprise about 400 pages; and each volume will, in most cases, contain two or more parts, each of which may be subscribed for separately. The extent of these parts will depend upon the amount of matter in hand, so that the subscription price for each cannot be fixed at present, but will be settled when the publication of each part is commenced. The following is a list of the principal subjects:—

Atmosphere, Water, Ocean (5), Rivers, Lakes, Springs, Floods, Glaciers, Land, Elevation and Subsidence of Land and Sea-Bottom, Denudation, Orography, Earthquakes, Volcanoes, Earth Magnetism, Marshes, Minerals, Stratigraphy, Rocks, Plants generally and in classified groups; Animals generally; Protozoa, Actinozoa, Hydrozoa, Echinodermata, Crustacea, Scolecida, Annelida, Mollusca, Myriapoda, Arachnida, Rhynchota, Orthoptera, Diptera, Coleoptera, Lepidoptera, Neuroptera, Hymenoptera, Pisces, Amphibia, Reptilia, Aves, Mammalia, and Man.

Subscribers' names only are asked for now. The sending of these will not involve any pecuniary liability, but will simply be taken as implying that the senders take an interest in the work, and will probably undertake to subscribe when asked to do so. At the moment of going to press the subject for which the largest number of names has been received is Ocean.

AQUEOUS VAPOUR: NOTES.

1854.

Livingston, Dr. *Journ. Roy. Geog. Soc.*, vol. xxiv. (1854.) (*rvp.*)

(*Page* 291.) When near Kamakama (in S. Africa) he observes, "The greater leafiness of the trees showed we were in a moist climate."

Maclaren, C. (*B.* 1854, 1.)

(*Page* 671.) The winds transport the moisture from the surface of the ocean to the interior of the great continents where it is precipitated. Mountains attract the moisture which floats in the atmosphere; they also obstruct the aërial current, and, presenting (*Page* 672) great inequalities of temperature, favour precipitation. He believes that in all countries with a summer heat above 70° the presence or absence of woods, and their greater or less luxuriance, may be taken as a measure of the amount of humidity [or, as the context shows, rainfall, not humidity].

1855.

Journ. Roy. Geog. Soc., vol. xxv. (1855.) (*rv.*)

[Nothing for notes on aqueous vapour.]

1856.

Austin, Robert. *Journ. Roy. Geog. Soc.*, vol. xxvi. (1856.) (*rv.*)

(*Page* 261.) Mt. Welcome, in West Australia, Oct. 21–25, 1855.—Weather very cloudy till towards night, when the wind veered to the westward, and the sky became clear, till about 2 A.M., when a heavy cloud-bank came up from the N.W., and soon spread in dense cumulus above us, but low enough to touch the hills. There was a rise of ·03 in. in the barometer every evening, when the cloudy canopy was dissipated.

Hopkins, Thomas. *Journ. Roy. Geog. Soc*, vol. xxvi. (1856.)
Read April 14, 1856. (*rv.*)

(*Page* 158.) There are certain areas of condensation of aqueous vapour, within and near to mountainous regions of the tropics, towards which general winds blow from parts far distant, constituting what are called the tropical trade-winds of the Atlantic and Pacific Oceans. The N. and N.E. winds that blow over the continents of Europe and Asia are aërial currents flowing towards partial vacua which are produced in areas of condensation, presenting evidence of the nature of the disturbances that produce these great movements of the atmosphere. When winds which are dry pass over the surface of the ocean, they readily take up moisture, which is subsequently condensed, creating a vacuum and producing rain at their termini. But when a partial vacuum in the

atmosphere is thus produced, heavier air presses in and flows as a wind from distant parts, not only over the ocean, but also sometimes over the low lands of continents, such as those of Asia and Europe. There are other winds which blow from dry to moist regions. In the northern portions of America, particularly during the winter, the air generally flows from the north, from one part that is comparatively dry and heavy to another part which has been rendered light by condensation of vapour brought by the tropical wind from the Atlantic Ocean to the Gulf of Mexico. The great mass of air, therefore, that passes over this continent in the winter flows southward to the Gulf of Mexico, in the neighbourhood of which, and against elevated land, the vapour that is at the same time brought from the tropical Atlantic is largely condensed. A part only of (*Page* 159) the vapour of the tropical seas passes into the Gulf of Mexico, as large portions of it turn northward over the Atlantic as well as over the Pacific Oceans, which portions are condensed on the western coasts of America and Europe. But the air which contained the vapour does not, after that vapour has been condensed, return to the tropics over the same two oceans, as in neither of them do north winds prevail. The moist south-west winds of the Atlantic, after being deprived of a large part of their vapour by cold, return in a dry state over the low lands of the continent; while the north-west winds of the northern part of the Pacific, after furnishing the rains of W. America, pass over Russian America and Behring Strait towards the Arctic Ocean, and return over the low lands of the central part of America as dry winds. Both of these land winds are dry, because they have been deprived of much of their vapour among mountains by cold; and they afterwards pass from colder to warmer latitudes, which renders them more capable of taking up moisture, and they press and flow towards their termini because there vapour has been brought from other parts by other winds to be condensed and to create a comparative vacuum in the atmosphere. Being in the northern hemisphere, these winds, with their peculiarities, are known to European meteorologists, but these meteorologists do not admit that the prime disturbing cause is the condensation of the vapour producing a vacuum in certain localities within the tropics. In the southern hemisphere we have facts of a similar character which are not equally well known. In that part of the world, as in the north, dry winds blow from cold to warm latitudes; and they also, as in the north, terminate in localities where a partial vacuum in the atmosphere has been created by condensation of vapour which has been brought from other parts. And thus we find that in both hemispheres cold and dry winds blow—not generally towards the equator as N.E. and S.E. winds, as is commonly assumed, but directly towards local areas of condensation of vapour, which are always found to be elevated land, against which, at the same time, warm and moist winds also blow. In the southern hemisphere there are not such broad continents as there are in the northern, yet the same flow of air over land rather than over water, (*Page* 160) from cool to warm latitudes, is observable in the former as in the latter. But there is ample breadth of ocean in the southern hemisphere, over which a cold aërial current might pass from the Antarctic Ocean to the tropics, and thus restore the equilibrium of pressure in a disturbed atmosphere in the way indicated in the Hadleian theory of winds, if the causes recognised in that theory were those which are really in operation. Over the whole Southern Ocean no palpable polar wind is to be found blowing to the tropics, such winds being confined to the comparatively small portions of land which exist in that hemisphere. Four separate winds in the southern hemisphere may be traced blowing from the south in a way that makes them correspond with the dry northern winds in the northern hemisphere; namely, two in America, one in Africa, and one in Australia. The first of these that may be noticed is the wind that blows along the low land of the western coast of S. America. It is first found about Valparaiso, say in lat. 33°, blowing moderately, but it increases in strength as it proceeds towards the equator, until it reaches the province of Guayaquil, a place which may be described as being in the most southern part of a very rainy district, included between 5° S. and 8° N.,

into which vapour is brought from the heated surface of the Bay of Panama, extending westward into the Pacific Ocean, and the Mexican and Californian Seas. Now, if an atmospheric current is made to flow from the polar to the equatorial regions in the way alleged in the Hadleian theory of winds, why have we not a S.E. wind blowing over the whole Southern Ocean between America and New Zealand, instead of the limited Peruvian wind over a narrow strip of land? In this wide range of open sea a west wind of a decided character blows across the part south of lat. 38°, and nearer to the equator a broad strip of calm occurs until the eastern trade-winds of the S. Pacific is reached; but over the whole of this extensive ocean no such S.E. wind is found blowing from the polar towards the equatorial regions as would certainly blow there if the Hadleian theory were true. The second dry American south wind is found (*Page* 161) on the east side of the Andes. It commences near the Straits of Magellan, and passes over E. Patagonia and the pampas of Buenos Ayres, approaching the great region of condensation that exists on the east side of the Andes; a region where the atmosphere must be made light by the large amount of vapour coming from the tropical Atlantic that is known to be there condensed, forming a partial vacuum, into which the cool and dry air passes from the line of country that has been pointed out. The (*Page* 162) dry air itself does not take sufficient vapour to produce a considerable vacuum at the place of its termination; nor does much rain fall, excepting among the Andes, to the south of say 25° lat. The vacuum that gives birth to this southern wind is therefore evidently produced by condensation of vapour, which is mostly brought up the broad valley of the Amazon from the tropical Atlantic Ocean, and that condensation, by producing an atmospheric vacuum, must be considered the prime disturber of the aërial equilibrium in this part of the world, which the influx from the south tends to restore. In like manner, Hopkins gives details respecting Africa, from which he infers that in the central part of Africa there exists a region of condensation (*Page* 165) of aqueous vapour, which vapour is brought principally from the Gulf of Guinea and condensed among mountains, producing a vacuum towards which the air from more southern parts presses and flows as a southern wind; and being carried into the vacuum, and ascending to a sufficient height, its own portion is cooled and condensed, increasing the vacuum and augmenting the rainfall in the area. As regards Australia little is known. There are extensive dry regions, but there do not appear to (*Page* 166) be any great areas of condensation. In the East Indian Archipelago there is an area of condensation of aqueous vapour probably equal in magnitude to any other on the surface of the earth. Currents of air are known to set in towards this area, and probably the dry south wind of Australia is one of those indraughts which only produces rain on the higher lands. It may be observed that some of the most southern lands in the south hemisphere have considerable rainfall where the winds just strike them. This (*Page* 167) must cause them to be drier in the regions north of them. In July 1853 Mr. L. Blodget described a dry wind which terminated in a rainless district. It (*Page* 168) blows from the Gulf of Mexico inland. But is it exhausted in a rainless district? Rather, is it not that it blows over the dry region and reaches to the sources of the Red River, Mississippi River, and other large streams. If heavy rain falls in a locality towards which a dry wind blows, we may safely infer that it blows towards a rain-made atmospheric vacuum? Should the part described by Mr. Blodget prove to be a district made rainless in summer by condensation in the country to the north of it, it will prove a striking instance of the power of vapour to cause a wind to blow towards the place where its condensation is occurring. The vacuum about the sources of the Missouri would be proved to be sufficient to draw air even from the Mexican Gulf, in opposition to the powerful influences that exist in other parts around that Gulf, and also to make the air pass northward over the rainless district described. For the sake (*Page* 170) of clearness we have confined our attention to the more general and permanent winds. The discussion of the smaller and temporary disturbances would have

made the matter obscure. The general laws which govern the changes in the atmo-(*Page* 171) sphere are usually not complicated. Under the operation of these laws certain localities have great influence in producing motion in the atmosphere, and creating the general currents in it which determine its circulation. Over the ocean evaporation is continually taking up vapour, which by its elastic force expands and diffuses itself through the gases; and the amount of heat thus taken up to be afterwards used in expanding the gases in particular localities is enormous. Through a difference in the laws of cooling by expansion of vapour and gases, this heat would in all parts be given out at certain heights, when the cold of the gases condensed the vapour, and rain would fall with considerable uniformity. But as there are certain elevated lands distributed over the surface of the earth, against these the vapour is largely condensed, and towards those lands atmospheric currents flow, or must flow, producing continuous aërial movements and ascents in the area of condensation. The ascents cause a boiling up and overflowing of large masses of the atmosphere in the higher regions, where they diffuse themselves. These localities of condensation may here be given in their order of importance. The first is found on the east side of the Andes, where the rivers La Plata, Amazon, and Orinoco have their sources. The second is in and about the Himalaya Mountains. The great Asiatic Archipelago is the third. The tropical African mountains may be next, giving rise to the Nile and Congo. Then follow the Rocky Mountains of North America, the mountains of Chili, West Patagonia, and Terra del Fuego, the Alps and (*Page* 172) mountains of central Europe, the Scandinavian and the British mountains. Over all these mountainous countries aqueous vapour is largely condensed, and the atmosphere is made to boil up and overflow each place in proportion to the amount of vapour brought for condensation, and the height to which the vertical current ascends. The air discharged above in due time comes down to the surface, and thus a general circulation of the atmosphere is established. There is no evidence that dry air ascends over hot plains to any considerable height. The higher currents in the atmosphere probably flow from the areas of condensation to the regions where the dry winds commence at (*Page* 173) the surface, deriving their supply from descending currents.

[The controlling influence of evaporation and of the condensation of aqueous vapour in producing the disturbances in the equilibrium which generate winds was fully and clearly enunciated by Daniell in 1823. The remarks made by Hopkins find a place on account of its giving his conception, or rather what may be inferred to be his conception, of the distribution and circulation of aqueous vapour. As it was difficult to give this without bringing in his more general ideas, no attempt has been made to separate them.]

Parish, Alfred. *Journ. Roy. Geog. Soc.*, vol. xxvi. (1856.) (*rv.*)

(*Page* 156.) In some parts of the equatorial regions the southern cyclone seems to rise from the surface at that point which represents the S.W. or S.S.W. winds, and the northern one at that representing the N.W. or N.N.W. winds; while in other parts, especially towards large continents, the due westerly winds appear to extend over many degrees of longitude. May this not be from local influences or differences in the humidity of the atmosphere causing a variation in the angle at which the surface strikes the surface diagonally.

1857.

Grant, W. C. *Journ. Roy. Geog. Soc.*, vol. xxvii. (1857.) (*rvp.*)

(*Page* 275.) In Vancouver Island a parching heat prevails from March to October, which dries up all the small streams. In the commencement of autumn dense fogs prevail, enveloping everything in obscurity.

Osborn, Sherard. *Journ. Roy. Geog. Soc.*, vol. xxvii. (1857.) (*rvp.*)

(*Page* 144.) In the Gulf of Azov, after the end of August, short fierce squalls set in from the northward, varied with S.E. winds, which are preceded by dense fogs. These true S.E. winds are sometimes turned into easterly winds by the land, but their character, and the fogs which accompany them, distinguish them clearly from the hot summer wind. Great and sudden variations of temperature are now experienced, which fully account for the squalls from the northward and the dense sudden fogs from the south. These squalls give plenty of indication by a dense body of black clouds in the quarter from whence they may be expected.

1858.

Hopkins, J. (*B.* 1858, 1.)

[Nothing appertaining to these notes which is not to be found in his earlier paper in 1856.]

1859.

English Cyclopædia. (*B.* 1859, 1.)

(*Col.* 973.) In the equatorial zone the air is clear till about two hours before noon, when the clouds begin to appear until rain sets in at noon. Towards evening the clouds disappear, and the sun sets in a clear blue sky. No rain falls in the night. (*Col.* 974.) During the rainy season the rains frequently flood the low and level country a foot deep with water, so that the atmosphere of such tracts is continually loaded with vapour and exhalations, which render the stars invisible at night, and are doubtless a principal cause of the unhealthiness of these countries.

English Cyclopædia. (*B.* 1859, 2.)

(*Col.* 984.) From what has been observed at Teneriffe, it seems that in all climates, the rainless tracts excepted, a considerable stratum of clouds commonly exists over the land, the inferior surface of which is at a height varying from 2500 to 3000 feet, whatever of cloud there may or may not be above or below that altitude.

Journ. Roy. Geog. Soc., vol. xxix. (1859.) (*rv.*)

[Nothing for these notes.]

1860.

English Cyclopædia. (*B.* 1860, 1.)

(Vol. iii. *Col.* 498.) The vapour plane where clouds form represents an area where the dew-point prevails and the cloud corresponds to the dew. A. de Candolle and A. (Vol. iv., *Col.* 150.) Henfrey infer from the distribution of the species that ligneous plants established themselves in northern and temperate countries when the climate must have been more humid and more cloudy than at present. [The greater dryness at present may be due to the destruction of forests, which formerly seem to have been (*Col.* 158) general.] If all the forests on the globe were destroyed the atmosphere (*Col.* 740) would be exceedingly deficient in moisture. The leaves of plants which thrive in the dry air of the tropics are large and succulent. In the tropics generally the degree of dryness of the air seldom exceeds 10° of Daniell's hygrometer. In tropical countries the air is saturated with vapour during the night, or at least it is

(*Col.* 752) seldom otherwise in the open air. As a general law it may be stated that the humidity [=high dew-point] of the atmosphere decreases from the surface of the earth upwards. The great dryness [= low dew-point] of the atmosphere near the summits of mountains has been frequently remarked by travellers. Biot observes that the fall of the mercury is a more certain sign of rain than is its rise of fine weather, since the ascent of the clouds is not necessarily accompanied by their dispersion. From the agitation produced by wind the upper regions of the atmosphere are often charged (*Col.* 794) with aqueous vapour. Hygrometry is that part of natural philosophy which (Vol. v., *Col.* 272) relates to the humidity particularly of the atmosphere. Early in a thunder-storm there is some alteration of temperature as well as considerable barometric (*Col.* 273) and hygrometric changes. Evaporation increases the electrical condition of the (*Col.* 708) air. [Since the Bibliography was published the statements in this column (*Col.* 709) have been entered from earlier publications.] Soon after sunrise in fair weather, the vapour near the earth having been precipitated by the night cold in the form of dew, and the sloping rays of the sun having little power to raise more vapour, the air is almost perfectly transparent, and every object has a clearness and sharpness of outline which it never has at any other time of the day. On our rivers and seas towards the end of summer, throughout the autumn, and the beginning of spring, the frequency and amount of mists are remarkable.

Grey, Earl de. (*B.* 1860, 2.)

(*Page* cxlv.) The prevalence of moist air, much or little cloud, can be predicated approximately of any place, although no observations have been made there. Cold dry (*Page* cxlvii.) air from a polar direction is heavier than warm moist air blowing from (*Page* cxlviii.) tropical or equatorial regions. Evaporation, rarefaction, or condensation of vapour in air, reduces its specific gravity, the two former by expanding bulk and rendering it lighter through mechanical diminution of quantity by falling to the earth in rain, &c.

1861.

Eaton, H. S. *Proc. Brit. Meteorol. Soc.*, No. 1. Nov. 1861. (*rv.*)

(*Page* 12.) Various theories have been advanced as to the cause of the increase of rain in hilly districts. One (the most commonly received) is, that a current of air saturated with vapour, on coming in contact with the cold hills, has its vapour condensed, which falls as rain. This cannot, however, be so; if it were, we should invariably have rain when in the winter months a warm and saturated S.W. wind succeeded a frost as long as the ground remained unthawed, instead of a thin surface-fog, as usually obtains. In the autumn, too, after clear nights the dew-point temperature is often higher than that of the ground and pavement, under which circumstances we find the vapour condensed on the surface, which appears wet in consequence. The true explanation is, that whereas the temperature of the air decreases $1\frac{1}{4}°$ F. for every 100 yards of ascent, the dew-point only decreases $\frac{1}{4}°$; if then a stratum of air, in which the complement of the dew-point is 5°, be raised through a vertical space of 1200 feet, (*Page* 13) the vapour which it contains will begin to condense into cloud. Now, let us imagine a south-westerly surface wind to be setting in from the Atlantic, at a temperature of 52° and a dew-point of 48°, as is frequently the case in autumn and early winter [in Devonshire]. On reaching the land a ripple is produced, and on crossing the Dartmoor hills the whole stratum is lifted up about 1700 feet. In rising through this extent the air expands and cools; at a height of 975 feet the cold produced by expansion will begin to condense the vapour into cloud, and all the hills above this elevation will be capped with fog, the temperature at this point being 48°; in a further

ascent the latent heat evolved by the process of condensation will prevent the air cooling as fast as it did, to the extent of nearly three-fourths the amount; so that at 1700 feet the temperature will not be lower than 47·3°; under favourable circumstances, however, rain will ensue. On passing the hills the mist sinks, becomes warmed under greater pressure, and evaporates.

English Cyclopædia. (*B.* 1861, 3.)

(*Col.* 928.) In general the lowest stratum of air above the earth contains the greatest quantity of aqueous vapour, and hence it might be expected that more rain should fall on low level plains than in elevated countries. The contrary is the fact, and this may be accounted for by the variety of currents among mountains and by clouds descending frequently on the summits of hills without descending to the plains.

(*B.* 1861, 6.) (*ra.*)

(*Page* 573.) During the eclipse of the sun, July 18, 1860, there was a marked increase of humidity at the various places where the eclipse was observed.

Journ. Roy. Geog. Soc., vol. xxxi. (1861.) (*rvp.*)

[Nothing for these notes.]

1862.

Bell, C. N. *Journ. Roy. Geog. Soc.*, vol. xxxii. (1862.) (*rvp.*)

(*Page* 247.) In the Mosquito country, towards the end of May, every day, towards the afternoon, the clouds which are brought over from the sea are piled in a dark bank (*Page* 248) to the westward. This gathering of clouds is occasioned by the land breeze, which begins to be prevalent now during the night.

Bellingham, W. (*B.* 1862, 2.)

(*Page* 110.) The recurrence of phenomena indicating the existence of a tide or belt of vapoury clouds, traversing the atmosphere alternately from pole to pole at regular intervals of 40 days, has for some years past attracted the author's attention. This tide, which would pass and repass the latitude of Peru at intervals of 20 days, may be connected with the Peruvian period of 20 days, at intermediate regions between the equator and the poles would return at longer or shorter intervals according to the (*Page* 111) latitude of the place. For example, from the time it passes northwards over London to its return to the same latitude would be about 10 days, if it moved at an estimated rate of 20 miles in an hour; its next return after going south would be in about 30 days. Owing to many counteracting influences it would be difficult to predict the effects of the tides. Under certain conditions of the atmosphere, however, it would probably produce storms and rain. Though the belt of vapour is supposed to be continuous, it is probable that some parts of it would be considerably in advance of others in those regions where least resistance is offered to its progress. The supposed periodic tide of 40 days would sometimes combine with the lunar atmospheric tide of about 27 days, and at other times be in opposition to it. The theory is founded upon observations in the latitude of London.

FitzRoy, R. *Journ. Roy. Geog. Soc.*, vol. xxxii. (1862.) (*rvp.*)

(*Page* cxxxii.) Air currents retain their characteristics for a considerable time. Thus we may have by deflection, for short times only, cold dry winds from the S.W., or warm

(*Page* cxxxv) moist winds from the north. With polar currents of air, clouds have a hard oily appearance; with the tropical currents they have a soft watery aspect, without hard edges or outlines.

Glaisher, James. *Proc. Brit. Meteor. Soc.*, vol. i. (No. 5, published Nov. 19, 1862.)

[Plate vii. He shows the balloon track rising to 23,500 feet, and cirri above, between five and six miles, the highest at over 31,000 feet. This was during the ascent from Wolverhampton.] The observations made during his balloon ascents (*Page* 259) [which are detailed in the paper] indicated that the temperature of the dew-point decreases on leaving the earth less rapidly than the temperature of the air, so that the difference becomes less and less till the vapour plane is reached, when they are usually together, and always most nearly approach each other (this elevation was about 5000 feet high); that immediately after leaving the upper surface of the cloud the dew-point decreased more rapidly than the temperature, and in the extreme high stations the difference between these two temperatures is wonderfully great, indicating an extraordinary degree of dryness and an almost entire absence of aqueous vapour. Under these circumstances the presence of cirrus clouds far above the dry region (*Page* 260) is very remarkable; on all occasions when seen they appeared still as far above as when viewed from the earth. Of what can they be composed?

Gregory, F. T. *Journn. Roy. Geog. Soc.*, vol. xxxii. (1862.) (*rvp.*)

(*Page* 428) N.W. Australia, 1861.—Latterly the wind was alternately S.E. in the morning and N.W. or westerly in the afternoon, the sky frequently becoming overcast. [By latterly is meant getting on for October.] The rainy season, from the observations of previous explorers, is from about the beginning of November on to March.

Herschel, Sir John F. W. *Meteorology*, 2nd Ed., 1862.

(*Page* 2.) Supposing there were no latent communication or transfer between the columns of air incumbent on adjacent parts of the earth's surface, the totality of atmospheric and climatic change in any given locality would be limited to periodical and perfectly regular fluctuations of temperature, and to the alternate generation and condensation of vapour, equally periodic and regular, immediately consequent on such fluctuations, over those parts of the surface occupied by water. No rain would ever fall or cloud form over any part of the land, which would be perfectly arid. Air (*Page* 17) contains on an average 0·45 per cent. of aqueous vapour. When aqueous (*Page* 25) vapour ascends by its levity it drags air up with it—not by heating it, but by mechanical impulse; and thus we see that the mere fact of a circulation of air in the atmosphere, in so far as that circulation is due to the generation and condensation of vapour, or even to the downward mechanical impulse of the fall of rain or snow, must of necessity cause a deficiency of sensible heat in the higher as compared with the (*Page* 48) lower regions. Mr. Glaisher's observations clearly show that the higher the cloud the greater is the radiation upward. Thus on nights uniformly and totally cloudy, the mean heights of the clouds being respectively 1700, 2800 and 3700 feet (which his peculiar situation enabled him to ascertain), the depressions were found to (*Page* 49) average 1·6°, 2·5°, 3·9°, clearly indicating the lower temperature of the higher clouds. Water freely exposed to the air evaporates at all temperatures, even when in (*Page* 50) the state of snow or ice; *cæteris paribus*, the amount of water evaporated is proportionate to the surface exposed to air. It is much greater, therefore, from rough and porous solid substances kept wetted (as for instance from moist soil or from vegetation wetted by rain) than from the surface of water itself, and from the latter (*Page* 51) when agitated by winds or lashed into spray than when tranquil. Vapour,

introduced into the air, acts as a moving power in two ways—first, by a simple addition of volume; second, by its less specific gravity, in consequence of which as soon as it (*Page* 52) is generated it tends to rise in the air by its buoyancy, and in so doing carries up much of the air with which it is intermixed, disengaging itself no doubt from it in its upward progress to become entangled with fresh particles, which again it raises upward to abandon them for others. In this way not only is its upward diffusion far more rapid than its horizontal, but in its struggle upwards it tends to produce an ascensional movement in the air itself, and thus to act as a powerful agent in the (*Page* 53) production of wind. In every case the condensation of vapour is accompanied with a mitigation of cold at the point where it actually takes place. It is clear, moreover, that the generation of vapour under any extensive region more rapidly than it is carried off by diffusion or otherwise, must be attended with an increase of barometric pressure, since the total weight of the atmosphere vertically over any region must be supported by the total area of surface, and equally so that its condensation, provided that the condensed water be abstracted from the atmosphere, must lead to a diminution of pressure. The contrary will happen if the vapour generated be carried off as fast as produced by such a general upheaving of the aërial strata over any region as shall subvert their equilibrium and cause them to overflow upwards and laterally. In such a case, since air also will be carried off bodily from the region and be replaced by vapour, the mean specific gravity of the whole aërial column and its total weight will be diminished and the barometric pressure lowered. This takes place on a most extensive scale over the intertropical seas. The temperature of the surface water in (*Page* 54) them is habitually very elevated (from 78° at the tropics to 83° at the equator) and varies very little. A steady and copious evaporation is therefore continually going on. Vapour, carrying with it air, is constantly thrown up beyond the levels of equilibrium, where it flows over and spreads itself out over the upper regions of higher latitudes. The immediate consequence is a habitual deficiency of barometric pressure at the sea level on the equatorial as compared with that on the extratropical seas. In a voyage to the Cape of Good Hope in 1833–4 the writer of these papers found the decrease from the tropics to the equator on either side to amount to 0·24 in. Schouw and Humboldt had previously noticed this fact. Air is less dilated by heat than by the (*Page* 55) introduction of vapour, but in both cases a local relief of pressure is equally produced. Winds subvert the solar climate and produce its real climate directly by transferring heat and aqueous vapour with its latent heat from one region to another; (*Page* 81) and indirectly by means of the oceanic currents they cause. The winds act indirectly as distributors of heat and moisture by producing currents in the ocean. [Apparently he attributes the great ocean currents mainly to wind influence.] The most (*Page* 84) immediate, though assuredly not the most obvious result of this state of things [that is, of unequal distribution of temperature and system of winds] is the habitual hygrometric or relative dryness of the higher regions in clear weather. This is shown by very demonstrative facts. Thus Deluc remarked that the head of his walking-stick always fell off in high mountain ascents from the shrinking of the wood. Every (Essays by Sir J. Herschel, 1835) act of precipitation withdraws from the total mass of air some portion of its entire amount of vapour. As such precipitations are constantly going on in some place or other, the atmosphere as a mass, though incumbent on a wet and evaporating surface, is necessarily always deficient in moisture; and for the very same reason every superior stratum is relatively deficient in comparison with that immediately beneath it, from which its supply is derived. In point of ultimate causation, then, there is a constant drain on the aqueous contents of the atmosphere arising from changes of temperature. This drain extends to all its strata, but while the (*Page* 85) lower renew their losses from a surface hygrometrically wet, the upper draw their supply from sources more and more deficient in moisture. What the equatorial depression of the barometer at the sea level, then, is to the system of winds, such is the

habitual hygrometric dryness of the air above the clouds to that of rain—at once an indication of a process in progress and an efficient agent in continuing it. Wherever such relative dryness exists, vapour, by its own expansive nisus, is in the act of transfer in an invisible state from one atmospheric region to another, and the rapidity of that transfer is proportional, *cæteris paribus*, to the degree of dryness. This by no means supposes a universally prevalent deficiency of vaporous tension. Complete saturation must exist at the points of evaporation and deposition, but at intermediate ones any amount of irregularity may prevail according to local circumstances. The method now (*Page* 86) adopted in preference to all others [for ascertaining the amount of vapour in the air], or the most simple and convenient in practice, and leading to results which a very severe examination has proved to be quite satisfactory, is the simultaneous observation of the wet and dry thermometers. The formula of reduction, as it results from Dr. Apjohn's investigations, is as follows:—Let t, t' be the respective readings of the wet and dry thermometers (in degrees Fahr.), h the barometric pressure in inches, f the elastic force of the saturated vapour at the temperature t, and F its elastic force at the dew-point. Then will

$$F=f.\frac{t'-t}{80}.\frac{h}{30}; \quad \dots\dots \quad (a)$$

Or,

$$F=f.\frac{t'-t}{96}.\frac{h}{30}; \quad \dots\dots \quad (b)$$

the equation (a) or (b) being used according as t, the reading of the wet thermometer, is above or below 32°; f is found from a table; and F being calculated from the above expression, the dew-point may be had from the same table used reversely; F known, the weight of water per cubic foot is found by multiplying the weight of a cubic foot of dry air at 30 in. (563·214 grains) by the specific gravity of steam for elasticity F; *i.e.* by $F \times 0{\cdot}6235$. Copious tables for facilitating the whole process have been published by Mr. Glaisher (1847). Although Hutton's theory of solution is exploded, its language, being convenient, is retained. When the air in contact with a radiating surface has (*Page* 91) been reduced in temperature to the dew-point, it remains saturated, and at the same time colder than that above it. On level ground, in a calm, little or no mixture of the upper and lower air will occur; but on a slope the cold air will run downwards, and mixing with the air below, if sufficiently near to saturation, will depress the mean temperature of the mixture below its resultant dew-point, and produce fog. If the low ground be occupied by water or marsh, as the air in it is sure to be saturated, copious precipitation will necessarily result. If dry, the mist produced will (*Page* 92) be less copious, and may not even take place at all. In the Weald of Kent, a district abounding in grassy slopes and branching valleys, in the calm clear nights which are there so frequent, beautiful instances of radiation fogs are of perpetual occurrence. Immediately after sunset dew commences; streams of cold air set downwards, following the line of shortest descent, their course being marked with mist, thin and filmy at first, but acquiring density in its downward progress, and by degrees filling the valleys with fog, which in the morning before sunrise presents exactly the aspect of a winding lake or river of water, whose surface, perfectly even and horizontal, runs a sharply-defined line round every promontory, and into every retreating nook. A (*Page* 93) radiating fog, once formed, tends to its own increase by radiating off heat from its own particles. When the warm current in the open ocean encounters a shoal, the lower water (of inferior temperature) is thrown up to the surface. The surface water, therefore, on the shoal is colder than that of the surrounding ocean, and the atmospheres (saturated at the respective temperatures) mingling, produce those fogs which are observed to be prevalent in such localities. The fogs of Newfoundland are a remarkable instance in point. Fogs, too, are produced in the neighbourhood of icebergs on a similar principle. The Arve, in its descent from Chamouni, occasionally presents the appearance

of warm water throwing up steam (though in fact many degrees colder than the air), from the mixture of the cold air above it with the saturated warmer air of the valley through which it flows. (Obs. August, 1821.)

Barometric Fogs.—The temperature of a mass of air may be lowered beneath the dew-point by the simple effect of its own expansion. This may take place in two ways: (*Page* 94) viz., first, by a rapid and considerable relief of barometric pressure from above; or secondly, by its own ascent into a higher region of the atmosphere. The first case takes place when the trough of an atmospheric wave passes rapidly over the place of observation. The fog so produced comes on for the most part suddenly and without any obvious cause. It is not rolled in from a distance by wind, nor does a moderate wind dissipate it. It is not confined to the surface of the ground, but extends at once to great altitudes. It does not resolve itself into rain, but disappears, when the atmospheric equilibrium is restored by the recondensation of the air and the reappearance of its sensible heat. Such fogs are very common, and are precisely analogous to the cloud produced in the receiver of an air-pump by a rapid partial expansion of the air. They want a name, and that of "barometric fogs" seems not inappropriate. There is a fog of not very frequent occurrence in our [= British] climate which comes on gradually in a perfectly calm state of the air, without any sudden or considerable diminution of barometric pressure, and which evidently arises from a gradual increase of humidity in the air, at length attaining the dew-point. Such fogs would seem not unnaturally to result from the quiet lateral diffusion of vapour as a gas from some neighbouring or slowly approaching mass of vapour-loaded air, in anticipation of its bodily arrival as a moist or rainy S.W. wind. To such a fog the epithet of "diffusional" may not (*Page* 95) improperly be applied. When a body of vapour is generated from any warm evaporating surface it ascends by its relative levity, losing sensible heat as well by its own expansion as by its bodily transfer into and intermixture with colder air. When clouds form in a calm state of the air, and the evaporating surface is limited in extent or irregularly distributed in patches (as over marshy ground, rivers, lakes, &c.), or if any other cause dispose the vapour to rise in columnar bodies of greater or less extent, the summits of these clouds are marked by protuberant masses or piles of clouds, with generally rounded outlines, which appear to repose on flat bases, indicating the vapour plane. To such clouds Howard gave the name of "cumulus." They abound in the calm latitudes of the equatorial seas, and form a distinguishing (*Page* 96) feature in the meteorology of that region. That the self-expansion of the ascending air is sufficient to cause precipitation of some of its vapour when abundant, is rendered matter of ocular demonstration in that very striking phenomenon so common at the Cape of Good Hope, where the S. or S.E. wind, which sweeps over the Southern Ocean, impinging on the long range of rocks which terminates in the Table Mountain, is thrown up by them, makes a clear sweep over the flat table-land (about 3850 feet high), and thence plunges down with the violence of a cataract, clinging close to the mural precipices that form a kind of background to Cape Town, which it fills with dust and vapour. A perfectly cloudless sky prevails meanwhile over the town, the sea, and the level country, but the mountain is covered with a dense white cloud, reaching to no great height above its summit, and quite level, which, though evidently swept along by the wind and hurried furiously over the edge of the precipice, dissolves, and completely disappears on a definite level, suggesting the idea (whence it derives its name) of a "table-cloth." Occasionally, when the wind is very violent, a ripple is (*Page* 97) formed in the aërial current, which, by a sort of rebound in the hollow of the amphitheatre in which Cape Town stands, is again thrown up just over the edge of the sea, vertically over the jetty, where we have stood for hours watching a small white patch of cloud in the zenith, a few acres in extent, in violent internal agitation (from the hurricane of wind blowing through it), yet immovable, as if fixed by some spell, the material ever changing, the form and aspect unvarying. [See Notes, 1823, Daniell,

p. 123]. The form and aspects of clouds are very indicative of the circumstances under which they are in the act of forming or dissipating. The form of the cumulus clearly (*Page* 98) indicates the act of self-dissipation in invisible vapour into the upper relatively dry air. Stratus may be considered as intermediate between cloud and fog, being chiefly formed at night, and under the influence of radiation either from the surface of a ground fog or from impurities floating in the air itself. The latter is remarkably the case in great cities in which coal is chiefly consumed as fuel, and gives rise to those dense, yellow, suffocating fogs which infest London in the winter months. It would seem that each particle of soot, acting as an insulated radiant, collects dew on itself, and sinks down rapidly as a heavy body. Stratus is also formed very suddenly on a higher level, when in a clear calm night the general temperature of the air sinks by radiation or by diminution of atmospheric pressure till at some definite altitude above the surface the dew-point is attained. Thus on the night of April 19, 1827, the (*Page* 99) sky up to 16 h. 16 m. sid. time being perfectly cloudless, and not a breath of wind stirring, stratus at a high level commenced in the eastern horizon, and in eight minutes had extended to the western, obscuring the whole sky, the calm remaining unbroken. In this case the velocity of propagation of the edge of the cloud from E. to W., or following the sun, could not have been less than 300 miles per hour. The filamentous structure of the cirrus clouds, occupying the highest regions of the atmosphere, clearly indicates them as either in the act of originating from the union of aërial currents running parallel to each other, or as the residues of dissolving cloud drawn out into fibres by the wind. The cirrus is said to be often a precursor of windy (*Page* 100) weather. The cirro-cumulus clouds usually float at great elevations, and often appear as a loftier stratum through the intervals of lower clouds. They are frequent in summer, and attendant on dry and warm weather. The cirro-stratus appears to result from the subsidence of the fibres of cirrus to a horizontal position, at the same time approaching laterally. It often precedes wind and rain. The cumulo-stratus would seem to be the modification of cumulus formed when the columns of rising vapour which go to form it arrive in an upper atmosphere not sufficiently dry to round off its summits by rapid evaporation, thus allowing them to spread horizontally and form flat-topped, mushroom-shaped masses, the upper parts of which are often curled by the wind of an upper current into cirrous wisps, or cleanly cut off by a horizontal plane, forming an "anvil-shaped cloud" with a lateral projection, generally considered as a precursor of wind below. The tendency of cumulo-stratus is to spread, overcast the sky, and settle down into the nimbus, and finally to fall into rain. When two strata (*Page* 101) of clouds on different levels tend to unite, it is evident that the intermediate region must be nearly or quite in a state of hygrometric saturation. The cloud then forms confusedly and in irregular masses through the whole region, and finally resolves itself into heavy rain. When cloud is present the sun's rays are of course prevented from reaching the earth directly, and their heat is diffused through the general atmosphere, thus softening and mitigating their ardour. When the sun shines on a cloud which absorbs its heat, the cloud itself is necessarily partially evaporated, and the vapour by its levity tends to produce an upward current, and thus to counteract the effect of gravity on the globules of which it consists. A globule of water 1-4600ths in. in diameter, in air of five-sixths of the density on the surface, or at the height of about 5000 feet, would have its gravity counteracted by resistance with a velocity of descent of one foot per second (supposing no friction and no drag), and even if the terminal velocity were reduced to half that quantity by these causes, would still require some such upward action to enable it to maintain its level, a circumstance which sufficiently accounts for the lower level generally observed of cloud during the night. It is more than probable that when it is not actually raining a cloud is always in process of generation from below and dissolution from above, and that the moment this process ceases, rain in the form of "mizzle" commences. In a word, a cloud in general would seem to be merely

(*Page* 102) the visible form of an aërial space in which certain processes are at the moment in equilibrio, and all the particles in a state of upward movement. The (*Page* 104) increased quantity of rain measured by the rain gauges nearest the ground is usually accounted for on the hypothesis that the cold rain-drop condenses moisture in falling through an atmosphere nearly or quite saturated. But this cause is insufficient, as rain falling from 12,000 feet, and bringing a temperature of 40° F. to 213 feet, would have its weight increased by $\frac{1}{24}$ only, or $\frac{1}{17}$ of the quantity to be accounted for. (*Page* 105) Visible cloud rests on the soil at low altitudes above the sea-level but rarely; and from such a cloud only would it seem possible that so large an accession of rain could arise. (*Note.*—These remarks were made in 1857. More recently, March 29, 1860, a paper was read by Mr. Baxendell to the Lit. and Phil. Soc. of Manchester on this subject. He arrives at the same conclusion as to the insufficiency of the mere condensation of vapour on the falling drops to account for the phenomenon in question, and concludes that it is impossible to account for it except by the admission of the existence of water not in the state of true vapour, but already deprived of its latent caloric—in the atmosphere—though not affecting its transparency, so that a shallow stratum of the lower and comparatively clear atmosphere may supply as much rain as a densely-clouded and much deeper stratum in the higher regions. Mr. Baxendell hesitates to admit that the water can be present in the actual state of water, on account of its invisibility. He adds a very remarkable fact recorded by Mr. Binney, who, in descending the shafts of deep coal mines, has observed that the drops of water which drip from the upper part of the shaft increase to an extraordinary size in their descent to the bottom). The (*Page* 106) greater part of the enormous evaporation of the equatorial seas is at once condensed, and discharged again in rain from the cumuli which marks its uprush into the higher and colder regions of the air, the rain being most continuous where the sun is most vertical, or in the region of calms. The trade winds themselves, coming from higher latitudes, are acquiring temperature and taking up moisture from the sea. The returning counter-currents having discharged their first overload of moisture, pursue their course aloft, free from cloud and relatively dry; and in the neutral interval between them and the opposite lower current, cloud is not generated or rain produced by the intermixture of the two, the upper portions of the trades not being saturated. The clouds which do occur in these winds belong not to their higher strata, but to (*Page* 107) a much inferior level, not exceeding 5000 or 6000 feet in altitude, while the medial line between the winds has nearly double that elevation. Such at least are the phenomena on Teneriffe, as seen by C. P. Smyth in August. Between the tropics the year is divided into a wet and dry season; the dry, when the sun is in the opposite hemisphere and the trade winds blow strong; the wet, when in the same, and approaching the zenith. In the neighbourhood of the equator, where the sun passes the zenith twice at several months' interval, there are two dry and two wet seasons. Beyond the tropics, where the anti-trade or returning current descends to the level of the earth's surface, and by degrees takes up the temperature of our milder latitudes, its vapour, held so far in abeyance, becomes available for the production of rain, unless inter- (*Page* 108) cepted by some mountain-barrier tossing up the stream, and prematurely precipitating its vapour. Where this obstacle does not exist, however, the rains are distributed in the extra-tropical regions with considerable indifference as to season; in some, indeed, a certain approach to a wet and dry season of the year prevails. Since, however, the deposit of water from the air must of necessity bear some rude proportion to the actual quantity *in transitu*, the amount of rain or snow which falls on any country must, on a general average, diminish as the latitude increases. The origin of (*Page* 126) aërial electricity has been traced with every appearance of probability to (*Page* 127) evaporation. Pouillet showed that electricity was developed only when chemical change attended the evaporation. The processes of vegetation in which water is abundantly separated from the other constituents of plants, and perhaps also other

vegetable processes, are also sources of electricity. Thus we are led to look to the immense evaporation both from sea and land, and to the vital processes going on in the latter, as furnishing at least the chief supply of electricity in the air. Volcanic eruptions and conflagrations contribute their quota. The periodic fluctuations of the (*Page* 156) barometer are annual and diurnal. The consideration of the former will enable us to form a neater conception of the mode in which the latter arise. When it is summer in one hemisphere, it is winter in the other. Hence the air generally incumbent on the heated hemisphere is dilated, and expands both upwards and laterally, not only by its increased elasticity, but also by the increased production of vapour. It therefore not only encroaches on the other hemisphere by lateral extension, but, what is far more influential, flows over upon it. In order to perceive clearly the nature of the process, we must separate in idea the aqueous and aërial constituents of the portion of the air so transferred. The generation of the former goes on in the heated atmosphere, and replaces, in part at least, the loss in pressure arising from the transfer of air, while in the other the excess of vapour so introduced is constantly undergoing precipitation, and is thus constantly being withdrawn from the total mass, leaving behind it, however, to accumulate, the dry air which accompanied it. Thus, if we regard the total barometric pressure as subdivided into that of the dry air and of the aqueous vapour, and denote the former by P, the latter by V, we see that the dry pressure is diminished in the hot and increased in the cold hemisphere without any countervailing action, while P is in process of increase from below by evaporation and of diminution from above by overflow in the former, and *vice versâ* in the latter. If, then, the observed barometrio pressure at every point in either hemisphere be analysed by calcu- (*Page* 157) lation into its two constituents, by taking account of the hygrometric state of the atmosphere, and subtracting from the total pressure, $P \times V$, the portion due to the amount of vapour present, the remainder ought to exhibit, as a general result, an excess of dry pressure, P, in the winter hemisphere over that in the summer. So far as observation has hitherto gone, this result is perfectly corroborated, though, unfortunately, there are not yet accumulated sufficiently numerous and extensive series of observations in which the effects of the aqueous pressure can be duly separated from the dry. As examples, we shall select the series from the Indian stations, Calcutta, Benares, Seringapatam, and Poonah, calculated by Dove from the observations of Prinsep, Sparmann, and Col. Sykes, as compared with that at Apenrade from those of Neuber, and with the results obtained at the meteorological observatories of Prague, Toronto, and Hobart Town:—

Stations.	P, pressure of dry air. Max. in	Min. in	Diff. in.	V, pressure of vapour. Max. in	Min. in	Diff. in.
Calcutta	Jan.	July	1·019	Aug.	Jan.	·551
Benares	Dec.	July	1·244	July	Dec.	·645
Seringapatam	Jan.	June	·455	May	Jan.	·217
Poonah	Dec.	July	·760	July	Dec.	·435
Apenrade	Feb.	July	·450	July	Jan.	·346
Prague	Dec.	July	·383	July	Jan.	·285
Toronto	Dec.	July	·271	Aug.	Feb.	·380
Hobart Town	July	Dec.	·218	Feb.	July	·125

(*Page* 158.) These differences are large quantities; but we see that as the maxima of P correspond in point of time with the maximum of V, it is only their differences which constitute the total or observed annual fluctuation of barometric pressure. Since, as observed, the annual fluctuation of V is the result of an excess of supply over expense in one hemisphere, and of expense over supply in the other, it may very well happen that the annual fluctuation of V in certain localities may exceed that of P, and, being in a contrary direction, may either neutralise the fluctuations of the gross pressure $P+V$, or convert it into one of an opposite character. This, however, is rarely the case,

and where instances of it do occur, as at the Sta. Fé de Bogota and Bangalore, they are for the most part readily enough accounted for by the influence of local peculiarities. If we consider that, in general, the values of P and V, regarded independently, fluctuate in opposite directions, and hence the maximum of the one corresponds, or nearly so, in epoch with the minimum of the other, we shall easily see that, representing P by—

$$P = A + B \sin.(\Theta + C) + B' \sin.(2\,\Theta + C') + \&c.$$

we shall have at least approximately for V an expression such as—

$$V = \alpha + \beta \sin.(\Theta + C + 180^\circ) + \beta' \sin.(2\,\Theta + \gamma')\ \&c.$$

the value of C in the term Θ differing by 180°, while those in other terms ($C'\gamma'$, $C''\gamma''$, &c.) may or may not stand to each other in a similar relation—the only condition being that they shall be such as to render the co-efficients BB', $\beta\beta'$, &c., all positive. The gross pressure $P+V$ then will come to be expressed by the form—

$$P + V = (A + \alpha) + (B - \beta) \sin.(\Theta + C) + M \sin.(2\,\Theta + N) + M'' \sin.(3\,\Theta + N'),\ \&c.$$

Since $B' \sin.(2\,\Theta+C')+\beta' \sin.(2\,\Theta+\gamma')$ may always be reduced to the form—

$$M \sin.(2\,\Theta + N),\ \&c.$$

Thus we see that the tendency of the cotemporary action of the two elements composing the gross pressure is—1st, to produce a mean annual pressure $(A+\alpha)$ equal to the sum of the separate pressures; 2ndly, to subdue the influence of the term depending on Θ by reason of the opposition of signs affecting B and β in the joint co-efficient B and β; and thus, 3rdly, to give a greater comparative influence to the terms depending on $2\,\Theta$, $3\,\Theta$. Now it will be observed that a series thus constituted of series of Θ, $2\,\Theta$, &c., when made to run through its whole period by varying Θ from 0 to 360°, will have only a single maximum and minimum when the co-efficient of $\sin.(\Theta+C)$ is large in comparison with those of the other sines; but when the contrary is the case, a double, or even triple or multiple maximum and minimum may result from such (*Page* 160) mutual relations among the co-efficients as may very easily occur. The principal terms nearly neutralising each other by their mutual opposition, leave the general character of the law of periodicity of the compound effect to be decided by the relations *inter se* of the subordinate ones, and thus is explained, without prejudice to the general reasoning in arts. 77, 78 [pp. 71–73] (which remain true as regards the form of the atmosphere as disturbed by the sun's action), the fact, which appears on first sight in opposition to that conclusion, that the annual oscillation of the gross barometric pressure presents in a great many localities the phenomenon of a double maximum or even a still more complex character. Thus, in Paris, to take a single instance, from a mean of eleven years' observations (1816–1826) the total pressure exhibits two maxima, in January and in July, the former being highest; and two minima, in April and October, the latter being (*Page* 161) the lowest. In the same way the diurnal oscillations may be accounted for. To simplify our conception of the diurnal oscillation we will suppose the sun to have no declination, but to remain constantly vertical over the equator. The surface of the globe will then be divided into a day and a night hemisphere, separated by a great circle passing through the poles coincident with the momentary horizon, and revolving with the sun from east to west in twenty-four hours. The contrast of the two hemispheres, both in respect of heat and evaporation, in this case will evidently be much greater than in that of art. 165 (p. 156), and therefore the dynamical cause, the motive force transferring both air and vapour from the one to the other, will be much greater. But, on the other hand, much less time is afforded for this power to work out its full effect; and long before this can be accomplished for any locality the circumstances are reversed and a contrary action commences. The causes, then, and the mode of their agency, are perfectly analogous in the production whether of the annual or diurnal oscillation; but

in the former the feeble acting cause is aided by the very much greater length of the period; in the latter, its superior intensity is in great measure neutralised by the (*Page* 162) frequency of its reversal. There is another consideration, moreover, which cannot be without a great effect in establishing a distinction between the two cases. By far the larger portion of the land is distributed over the northern hemisphere, and of the water over the southern. The former is more uniformly terrene, the latter is more uniformly aquatic; and as, under the circumstances now considered, the transfer of air does not take place in the direction of meridians, but at right angles mainly to their direction, we should be led to expect that the amount of counteraction in the diurnal fluctuations of the dry pressure p by those of the wet v would be, generally speaking, very different in the two hemispheres, and that therefore the extent of fluctuation in the gross pressure $p+v$ would, generally speaking, present a corresponding difference. A sufficient amount of observations has not yet been accumulated to bring this conclusion to the test of experience; but we cannot help remarking that the very same cause (the excess of water on the southern hemisphere), acting according to the difference of conditions, ought in the case of the annual oscillation to result in an average uncompensated action on the dry air, urging it towards the northern hemisphere, and to its replacement, bulk for bulk, by vapour, which being lighter than air, [is assuredly one, and it may be the most efficient] of the causes of the generally lower atmospheric pressure over the Southern Ocean—a certain percentage of the due proportion of dry air (*Page* 163) being permanently driven out and prevented from returning by the constant outflow of vapour. That the double maximum and minimum of the barometric march really originates by the approximate destruction of the second term in the series—

$$(A+\alpha)+(B-\beta)\,.\,\sin.\,(\Theta+C)+\beta\,.\,\sin.\,(2\,\Theta+\gamma),\ \&c.$$

owing to the opposite march of the dry and wet elements of the total pressure, has been put out of doubt by the calculations of Dove. Yet there are localities where there is an apparent double maximum in the dry-pressure itself. We have seen that moisture in (*Page* 169) the form of clouds, or even in that excessively divided yet unevaporated state which is sufficient to injure the transparency of the atmosphere, and which must be confessed to belong to the yet unresolved problems of meteorology, produces absorption of the sun's rays and the conversion of sensible into latent heat. The diurnal march of temperature, then, in the general atmosphere, is intimately connected with its hygrometric state, and especially with its degree of relative dryness. And for the same reason that the heat of the day is mitigated by the evaporation of the diffused moisture, so is also the cold of night by its deposition, and hence arises a phenomenon of very general prevalence, viz., that the difference between the daily and nightly extremes of temperature or the extent of its diurnal fluctuations is greater in summer than in winter; or rather, to speak more generally and in language applicable alike to inter- and (*Page* 170) extra-tropical localities, in those seasons when the air is relatively drier or moister. In fact, it is evident that when the air is relatively dry, evaporation during the day is more active, and a larger portion of the incident heat becomes latent. On the other hand, as it is necessarily the dew-point which limits (at least approximately) the temperature of the lowest stratum at night, since in the act of condensation the vapour gives out its latent heat, and therefore so long as the supply is continued prevents its further depression the further removed from saturation the air is, the greater depression can be effected by radiation before that limit is reached. The near coincidence of the dew-point with the lowest nightly temperature, at every season of the year, has been shown by Anderson from observations made at Kinfauns Castle during the year 1815; and the calculations of Kämtz show that the difference between the daily extremes of temperature is universally greatest in those months of the year when the (*Page* 171) relative dryness of the air is greatest. The greater uniformity of an insular as contrasted with a continental climate is at least partly referable to the same cause,

viz., the alternate conversion of sensible into latent heat, and *vice versâ*, by the evaporation and condensation of moisture disseminated through the atmosphere during day and (*Page* 191) night. With the exception of a few very limited regions in which fogs are (*Page* 192) habitually prevalent, and certain points here and there occurring in which rain is almost constantly falling, the general state of the atmosphere is one of more or less hygrometric dryness; so that, as a rule, evaporation may be considered as going on continually over the whole surface of the globe, being only interrupted where that surface is, during certain hours of the night, cooled by radiation below the dew-point. During these the earth is actually abstracting moisture from the air—at all other times supplying it; but far more copiously during the day than during the night. Meanwhile, the very highest regions of the atmosphere being from time to time drained of their moisture by precipitation, there is always a demand for vapour upwards, which is no way intercepted in its ascent by the existence of a region where it assumes for awhile a visible form, and which can only be looked upon as a temporary halting-place, the upper surface of the cloud evaporating while the cloud itself is renewed by condensation of ascending vapour at the lower; unless, indeed, the radiation from the cloud itself should for a time so far lower its temperature as to suspend for awhile, or even reverse, the process. At the epoch of maximum cold, when the surface of the earth is at or near the dew-point, the hygrometric state of the air to a considerable altitude is near saturation, and frequently either a stratus cloud rests on the ground or exists at a much lower (*Page* 193) altitude than in the day; and when this is not the case, still the whole column of air, by reason of the general depression of temperature, is much nearer to its point of saturation than in the daytime. It is the practice of meteorologists to designate by the expression "humidity of the air" the degree of its approach to complete saturation with vapour, and to give precision to this language by attributing to that degree a numerical value, viz., the ratio of the quantity of vapour actually present per cubic foot to that which would exist per cubic foot were the air saturated, or were the dew-point identical with the actual temperature. Thus a scale of degrees of humidity is formed, 1·00 being that of complete saturation, and 0 that of absolute dryness. In this sense of the word it will of course be readily understood that a low degree of humidity is compatible with the presence of a large quantity of aqueous vapour. It is not the vapour as such, but its readiness to be deposited in a wet state on a surface but little lower in temperature, that is intended to be expressed. To obviate the discordance between this language and that of common parlance, the terms relative humidity and relative dryness are sometimes used. As a general meteorological fact, however, there is not merely a want of accordance, but an actual opposition between both the diurnal and annual progress of the "degree of humidity" or "relative humidity" of the air and (*Page* 194) the tension of vapour as indicated by hygrometric observation. To take the case in hand—the diurnal variation—we have seen that at those epochs of the night when the temperature has reached its lowest point, and dew is either actually deposited or nearly so, the humidity is at its maximum. But it is precisely at that moment that the supply of vapour from the earth—having been for several hours cut off, or even a reverse process in progress, while yet vapour has been diffusing itself into the non-saturated regions aloft, and is still continuing to do so—the actual amount of moisture per cubic foot is small, and is still in process of diminution. This epoch is usually a little before sunrise. As the day advances the temperature increases, and becomes more and more in excess of the dew-point. The air therefore becomes relatively drier, evaporation goes on more rapidly, the lower strata become fuller of vapour, as measured by its tension, which at length becomes such as to keep pace with the upward diffusion, which now in its turn is stimulated. The cloud level, or vapour plane, rises, and if the night has been clear, the air calm, the sun powerful, and the soil wet, the appearance of cumuli soon begins to render visible testimony to the nature of the process in progress. When the heat of the day has reached its minimum, the process is in its greatest

activity. The humidity has now reached its maximum, and the evaporation, which is in the direct ratio of the temperature and dryness, its minimum. From this epoch, (*Page* 195) however, the supply of vapour from below being most copious, while the temperature no longer increases, it is evident that the humidity must begin to increase, while the tension also, for a longer or shorter time, will do the same, until by the decline of the sun the increase of humidity so far puts a stop to the evaporating process as to render it barely competent to supply the expense of upward diffusion, at which moment the tension becomes a maximum, and from which it also decreases, and continues to do so, the humidity increasing during the remainder of the twenty-four hours until next sunrise, when the same cycle of causes and effects will recur. Such at least will be their succession in calm and clear weather and in a normal state of circumstances; and as regards the generally contrary march of the relative humidity as compared with that of the temperature and the vapour tension, such is really the course of the phenomena. The epochs, however, and the order of priority, are obviously very liable to be disturbed by a variety of circumstances, among which the most influential are rain, winds (especially such as recur in daily periodicity, as sea and land breezes), and cloud, which cuts off the sunbeams from the soil and puts a stop to the increase of evaporation before the temperature has attained its maximum, thereby tending to bring the epoch of maximum tension towards coincidence with that of maximum heat. We find, for example, on comparison of the three elements in question, as derived from six years' (*Page* 196) two-hourly observations at the Royal Observatory at Greenwich (1842–1847), the following results :—

	Maximum.		Minimum.	
Temperature .	55·22° F.	1 h. 20 m. p.m.	44·85° F.	4 h. 10 m. a.m.
Vapour tension .	·345 in.	1 h. 20 m. p.m.	·303 in.	3 h. 40 m. a.m.
Humidity . .	·938	4 h. 30 m. a.m.	·753	1 h. 20 m. p.m.

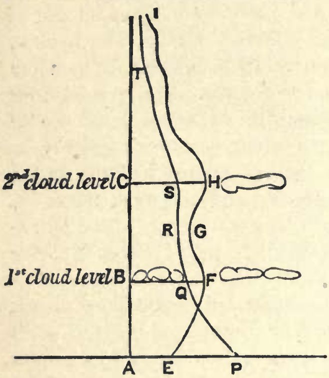
where it should be observed that the amount of cloud at Greenwich is a maximum at 0 h. 20 m. p.m., at which hour 73 per cent. of the sky, on a general average, is covered; and a minimum at 9 h. 44 m. p.m., when 60 per cent. of cloud prevail; the general average of the year being two-thirds cloudy. The annual march of humidity and vapour tension, as compared with that of temperature, depends on the same principles, and is governed by the same laws; the humidity, however (as is also the case with the diurnal cycle), being much more regular in its progress than the vapour tension, and the limits between which the latter element oscillates being much wider, as might be expected from the greater duration of the cycle, and the consequently longer time given for the causes in action to work out their full effect before removal. Thus at Greenwich the annual maxima and minima and their approximate epochs, as appears from the series of observations already referred to, are for the

	Annual Maximum.	Annual Minimum.
Temperature .	63·37° F. in July	34·20° F. in Jan.—Feb.
Vapour tension .	·466 in. in July	·195 in. in Jan.
Humidity . .	·930 in Jan.	·783 in June

(*Page* 197) Locally and temporarily nothing can be more capricious than either the humidity or vapour tension as we ascend into the higher regions. Meteorologists, from Saussure and De Luc downwards, have sought in vain for anything like a regular law of decrement like that which, at least approximately, prevails respecting temperature. Mr. Rush relates that in his sixteenth ascent to the height of 19,400 feet in the Nassau balloon, June 29, 1850, with Mr. Green, they traversed a stratum of air 8600 feet in thickness, in which absolute hygrometric dryness, the zero of vapour tension, existed. This must of course be received with some reserve; but it suffices at least to show that in regions of the globe where cloud is the rule and pure sky the exception, masses of air are occasionally intermingled with the generally moist atmosphere, which would seem

to have been all but absolutely drained of their moisture, either by long sojourn in the polar regions or in the highest and coldest strata of the atmosphere. Meanwhile, at the ordinary levels we know little at present of the average or climatic distribution of aqueous vapour. Of some things, however, we may be certain, viz.: 1st, That on the open ocean, far from land, the dew-point in the daytime can never be many degrees below the actual temperature of the air, and at night must always be very nearly identical with it. 2ndly, That the mean vapour tension in hot climates must neces- (*Page* 198) sarily be greater than in cold. 3rdly, That, *cæteris paribus*, the relative humidity of the air must be a maximum over the sea and a minimum in the interior of continents, especially where there is much sand, which allows the rain-water to sink, and which speedily dries at the surface; or much bare rock, which, never being more than superficially moistened, affords no supply of vapour to the air. For it is obvious that in such regions there must be less evaporation for an equal incidence of sunbeams; that, therefore, less of the heat will become latent, and their efficacy in heating the air will be in consequence greater, so that the temperature will rise in the daytime faster than the dew-point, and that in an increasing ratio; and, moreover, that from the very combination of these causes there will be less tendency to the formation of clouds over such regions, and therefore a greater amount of direct sunshine thrown on the soil. Thus we have a system of mutually reacting causes and consequences, all tending to exaggerate both the heat of the climate and its relative dryness; the only counteracting power being that of radiation, both diurnal and nocturnal, but especially the latter. Where, in addition to all these causes, those winds which blow from warmer regions or from tropical seas, before arriving at the place in question, have to pass over lofty mountain ranges, and have been chilled in so doing, and drained of their moisture by the precipitation of snow or rain, it may well be imagined that a (*Page* 199) state of extreme aridity will prevail. 4thly, and lastly, we may perceive that the upper regions of the atmosphere—not only as being colder, and therefore incapable of retaining without deposition a quantity of vapour equal to that of the lower —must be habitually and on a general average drier than the lower; though the existence of cirrus clouds at very high levels (certainly sometimes exceeding 30,000 feet) sufficiently proves that even at such altitudes saturation with moisture occasionally takes place. During the sojourn of Mr. P. Smyth on the Peak of Teneriffe the aridity of the air was found to be always excessive. On one occasion at Guajara (alt. 8843 feet) the depression of the dew-point below the temperature of the air was observed to be no less than 54° F. In actual cloud (although in the earlier history of hygrometry the fact was questioned owing to the imperfection of hygrometers used) both common sense and observation go to prove that the extreme point of humidity is attained, since where water is bodily present in every cubic inch of air, and refuses to disappear by evaporation, a state of absolute saturation must exist. Hence we are led to some singular enough conclusions with respect to the law of decrement of humidity as distinct from (*Page* 200) vapour tension. In the daytime, so long as the sky is cloudless over any spot, it is evident that there is no point in the aërial column above it at which the dew-point is surpassed so that the supply of moisture from below is carried off by diffusion upwards, and it will depend entirely on the copiousness of this supply, and the rapidity with which it ascends into the higher regions, whether, as the day advances, the vapour tension and humidity shall follow a contrary or similar progression. If the supply be abundant and borne up rapidly to a colder level, a cloud will be formed, and it is obvious that for some time before its actual visible appearance the air in that region where it is about to be formed must be gradually approaching saturation, and attain it at the moment of deposition of the first molecule of water in a liquid state. From the ground, then, up to the vapour plane, wherever such plane exists, whatever be the law of vapour tension, the humidity (with, perhaps, some interruptions in respect of regularity) continually increases up to 1·00, its natural limit, which it maintains

through the whole thickness of the cloud stratum. This surface passed, the upper surface of the cloud performs, to all intents and purposes as regards the higher atmosphere, the office of a lake, being a thoroughly wet surface on which that atmosphere reposes. Henceforward the law of decrement of moisture will be the same as (*Page* 201) it would be over the sea itself under the same circumstances of temperature and pressure. Nor does anything prevent (the sun striking on and evaporating it) why a second layer of cloud should not be formed again at a higher level, and so on—a phenomenon, in fact, of no rare occurrence. In such a case, if we take the height for an abscissa, as AB, the curve of humidity will be an undulating one, such as EFGHI, attaining its maximum 1·00 (= BF or CH) at F or H, and having a minimum between them as at G, while the curve of tension PQRST follows a progression totally different, the relation between any pair of their respective ordinates CH, CS being that which subsists between the temperature, tension, and humidity generally, a relation expressible by the equation



$$V = H \cdot \phi(t),$$

where V is the vapour tension, H the humidity, and $\phi(t)$ the function of the temperature t, which expresses the force of saturated vapour at that (*Page* 203) temperature. The winds are originally caused by the equatorial heat and generation of aqueous vapour, or by extensive local agencies of the same kind elsewhere. (*Page* 204) Dove, in his 'Meteorologische Untersuchungen' (1832), has succeeded in exhibiting in a very distinct manner, by an extensive induction from observations in almost every region of the globe, the close and immediate dependence of all the three great meteorological elements, temperature, moisture, and atmospheric pressure, on the direction of the wind. In other words, assuming Θ to represent the angle which that direction makes with the meridian of the place, any one of these elements is found to be expressible on an average or mean value during a whole year or series of years by the equation of the form—

$$E = A + B_1 \cdot \sin.(\Theta + C_1) + B_2 \cdot \sin.(2\,\Theta + C_2) + \&c. \quad . \quad . \quad (a)$$

The mode in which a law of this kind may originate is not difficult to understand. Suppose, first, the earth without diurnal rotation and the sun to move round it from east to west, and at any given spot (suppose in the north hemisphere) let a wind blow direct from the south with a certain force and during a certain time, this will bring over the place of observation the warmth and moisture of a latitude more southerly (suppose) by 10°. But from the eastward or westward of south, at an angle Θ with the meridian, the atmosphere of a place 10° remote, measured in a great circle, will be still transferred to the place, but owing to the inclination of the path only $10° \times \cos.\,\Theta$ more south. If, therefore, the former wind brought with it an accession of temperature or moisture, represented by e, this will bring the accession $e \cdot \cos.\,\Theta$ proportional to the difference of latitude travelled over. It may happen, however, from the circumstances of the locality that the warmest or moistest region in the neighbourhood may be not due south of the place, but in a direction making an angle 90° − C with the meridian. In this case, then, the extraneous temperature or moisture so induced will obviously be represented, not simply by $e \cdot \cos.\,\Theta$, but by $e \cdot \cos.(\Theta + C - 90°)$, or $e \cdot \sin.(\Theta + C)$. As the effect of the earth's diurnal rotation is to cause the wind to veer, the wind from the southern region will have more or less westing in it at the place according to circumstances. The effect of a wind will depend upon its degree of frequency and duration. Dove and others find

(*Page* 207) that in the wind rose there are two points not far from diametrically opposed to each other; the one in the neighbourhood of the N.E. point, the other in that of the S.W., from which, when the wind blows, on the long average, both the temperature and the vapour tension have their maxima and minima, the former at the N.E. and the latter at the S.W. The same, or nearly the same, points indicate reversely the maximum and minimum of barometric pressure. There are deviations according to localities. On (*Page* 208) the whole, however, for each locality and for each of the three elements in question it is found practicable to represent its variation in terms of the azimuths Θ of the direction of the wind by the expression

$$E = A + B_1 \,.\, \sin.\,(\Theta + C_1) + B_2 \,.\, \sin.\,(2\,\Theta + C_2).$$

in which C is very nearly the same angle for all of them, and in which B_2, the co-efficient of the term of the second order, is found to be smaller in comparison of B_1, that of the first. And it is evident that the total barometric pressure $P+V$ and the vapour pressure V, having both this form of expression, their difference P, or the pressure of dry air, will admit of a similar one by a proper determination of its co-efficients, which are easily deduced from those of its component elements by putting

$$P_0 + P_1 \,.\, \sin.\,(\Theta + C_1) + P_2 \,.\, \sin.\,(2\,\Theta + C_2) + V_0 + V_1 \,.\, \sin.\,(\Theta + C_1) + V_2 \,.\, \sin.\,(2\,\Theta + C_2)$$
$$= P'_0 + P'_1 \,.\, \sin.\,(\Theta + C'_1) + P'_2 \,.\, \sin.\,(2\,\Theta + C'_2),$$

where P' represents the mixed pressure and the several numbered and accented letters the respective co-efficients of the general formula, and which, reduced by the usual trigonometrical transformations, afford equations by which any one set of these (*Page* 209) values may be easily derived from the other two. It is evident, moreover, without any calculation of this kind, that since the elastic power of the vapour has its maximum at the S.W. point, where the total barometric pressure has its minimum, the dry pressure P must have its minimum there also; in other words, that C_1, being approximately $= C_1 + 180°$, C' will be nearly identical with C. Dove further finds that these co-efficients are severally and separately, like all meteorological local elements, periodical functions of the season of the year or of the sun's mean longitude. A similar set of relations ought to subsist in the south hemisphere, *mutatis mutandis*; that is to say, with the maxima and minima at south-east and north-west. As an example of the results obtained in this branch of meteorological inquiry we shall here set down the values of the co-efficients in the expression $E = A + B_1 \sin.\,(\Theta + C_1)$, &c., as calculated by Prof. Johnson from the series of meteorological observations made under his superintendence at the Radcliffe Observatory at Oxford. These are (Radcliffe Obs. 1854, p. xxvi) for the

	A.	B_1.	C_1.	B_2.
Temperature, T.	48·60° F.	2·34°	254·35°	0
Dry pressure, P.	29·404 in.	·108 in.	75·33	0
Vapour pressure, V.	·307 in.	·026 in.	259·39	0

where it will be noticed that $180° + 75°\ 33' = 255°\ 33'$, and therefore, comformably to the theoretical views above delivered, the dry pressure has its minimum very nearly corresponding to the maximum of temperature and of vapour pressure. Whenever, as in this case—which is the most common—the terms of the second and higher orders are inseparable, or nearly so, the coefficient B determines the maxima and minima, so that the respective values of $2\,B_1$ will express the total amount of fluctuation in temperature, pressure, &c., at the stations which have their origin in changes of wind. It is very easy to perceive that, with this dependence of the great elements of the weather upon the direction of the wind, the other features which stand to them in the relation either of immediate consequences or proximate causes must go hand in hand, such as cloud, rain, &c. For instance, at Karlsbad, from the calculations of Eisenlohr it appears that during the prevalence of south wind, one day out of 17·29, on an average,

(*Page* 211) only is free from cloud, and during that of north-east one out of 3·04; the intermediate winds being accompanied by intermediate degrees of frequency. So also for the other elements. The tables at the end of this work afford numerous (*Page* 212) and striking exemplifications of these laws, especially as regards the contrary march, both annual and diurnal, of the humidity and vapour tension, the greater range of the annual as compared with the diurnal fluctuations, and the dependence of the average amount of the vapour present in the air, and the extent of both kinds of fluctuation in the latitude.

(*Page* 230.) In describing the cause of polarisation of skylight, he decides it cannot be due to the refractive action of ice, nor of water, nor of reflection of air upon air. Newton's explanation is the least unsatisfactory; he assigns it to the reflection of light on their transparent particles. [H. does not say more, but seems to hint that these particles are vapour, as he states that its explanation will probably be found to carry with it that of the blue colour of the sky itself. If so, then it may be that facts connected with this subject which are given under "Climate: Luminous Rays" may afford clues as to the distribution of vapour. At present the connection is not sufficiently clear to warrant notes being entered here; but when the phenomena of polarisation afford data of this kind such notes may be given here.]

(*Page* 236.) In certain phases of an auroral display indications of a very unequivocal character are afforded of a distribution of a material substance in forms which, could they be seen under ordinary circumstances, would be called clouds. We allude to those luminous bands extending across the sky, and patches of auroral light which are either stationary or nearly so in the sky, but which, when attentively watched, are usually perceived to be slowly drifting southwards. These, perhaps, belong to com- (*Page* 237) paratively less elevated regions, and are, perhaps, in some cases identifiable with the very highest perceptible cirrus cloud.

Proc. Brit. Meteor. Soc., vol. i. 1863. (No. 2, for Jan. 1862.) (*rv.*)

(*Page* 116.) Notice of "Meteorological Tables," by G. H. Simmonds. 1861.

(*Page* 117.) Table XVII. shows the weight in grains of a cubic foot of vapour, assuming that at 212° it weighs 257·13 grains. Table XVIII. shows the weight of a cubic foot of air saturated with moisture under a pressure of 30 in. from $-20°$ to $+120°$. (*Page* 129.) Fisher, in 1845, says that the principal displays of the aurora occur in the vicinity of the edge or margin of the Frozen Sea, and that it is an electrical phenomenon, and arises from the positive electricity developed by the congelation of these [humid (by Editor of Proc.)] vapours, and the consequent induced negative electricity of the upper and surrounding portions of dry atmosphere. It is the accompanying indication of the restoration of the electrical equilibrium, which equilibrium is restored by the intervention and conducting power of minute frozen particles, which particles are rendered luminous by the transmission of electricity. In early winter, before the sea was frozen over, the aurora had a diffused character. As the winter advanced and the edge of the ice became more remote, so the aurora diminished in splendour, assumed a low arched appearance, and was seen only in the direction of open waters. Its height above the surface of the earth is very inconsiderable in high latitudes. The sudden deposition of extremely minute frozen particles when auroral displays took place near to the zenith was several times observed by the author. Joslyn, in 1838, states among other conditions that it [the aurora] requires for its development a cold adequate to the crystallisation of aqueous vapours; that crystals of snow more minute and simple than those which produce halos, are always present in the atmosphere, above the region of ordinary clouds, during the appearance of this meteor. Fisher considers that perhaps the strongest proof of the important agency of these particles in an auroral display is to be derived from the fact that the auroral light can be distinctly traced to those localities where humid vapours

are known to be undergoing rapid congelation, and where such particles must in consequence abound, and that in the usual arch formation, whatever may be the nature of the night, yet the auroral fringe clearly arises from the illumination of the frozen particles which are formed from the extreme portion of the vapours being under the influence of the cold atmosphere immediately above them. Fisher obtained sufficient evidence of the direction of the situation of the open water from the dark masses of vapour known as sea-blink. The upper limit of the auroral arch was generally dark and dense, as if charged with humidity; the lower, being nearer the water surface, was warmer and more transparent. When ice breaks up by the action of spring tides, and water is suddenly exposed, a difference of more than 70° F. is often found between the water surface and the atmosphere immediately over it; so that the latter becomes immediately impregnated with the extremely minute frozen particles known as frost- (*Page* 130) smoke; and he conceives that the alternate opening and closing of the ice, by which means different portions of vapours are detached from the surface of the sea consecutively, give rise to the appearance of different concentric arches of aurora. Vertical streamers are columns of icy particles in the act of restoring equilibrium between higher and lower strata. Low temperature and humidity are, in his opinion, the conditions required for the production of aurora, and hence the water limits of the Frozen Sea will be most favourable to the production of the aurora, from the circumstance of there being there the greatest supply of humidity. He infers that the auroral zones will not approach nearer the poles than the margin of fixed ice, for lack of humidity.

(*Page* 135.) De la Rive considers he was the first to notice the close connection between auroras and the small icy particles suspended in the elevated regions of the air. Secchi concludes that the character of winter clouds in the polar regions is different from that of the ordinary clouds, and that the appearance of these latter clouds at the poles is a signal, the harbinger of the fine season and of humidity, whilst the auroræ then disappear; that the aurora does not appear unless when the weather is humid; that even when the sky in the polar regions appears limpid it is nevertheless filled with small icy particles. The fact that the aurora is contemporary with a very dry atmosphere, the temperature of which is below 0°, containing small icy particles, may be considered beyond all doubt.

Proc. Brit. Meteor. Soc., vol. i. 1863. (No. 2, for Jan. 1862.) (*rv.*)

(*Page* 167.) Espy (1834) believes that all the phenomena connected with storms are explained by the following theory. When the air in any locality acquires a higher temperature or a higher dew-point than that of surrounding regions, it is specifically lighter, and will ascend; in ascending it comes under less pressure and expands; in expanding from diminished pressure it grows colder—about a degree and a quarter for every 100 yards of ascent; in cooling as low as the dew-point (which it will do when it rises as many hundred yards as the dew-point at the time is below the temperature of the air in degrees of Fahrenheit) it will begin to condense into cloud; in condensing its vapour into water or cloud it will evolve its latent caloric; this evolution of latent caloric will prevent the air from cooling so fast in its further ascent as it did in ascending below the base of the cloud now forming; the current of air, however, will continue to ascend and grow colder about half as much as it would do if it had no vapour in it to condense; and when it has risen high enough to have condensed, by the cold and expansion from diminished pressure, one-hundredth of its weight of vapour, it will be about 48° less cold than it would have been if it had had no vapour to condense nor latent caloric to give out—that is, it would be about 48° warmer than the surrounding air at the same height; being lighter it will ascend and spread out gradually, overlapping (*Page* 168) the air all round and causing the barometer to rise around the storm and to fall in the centre, and, being under less pressure, will ascend, carrying the vapour it

contains with it, and so continue the process of cloud-forming. The phenomena of tornadoes, hailstorms, and whirlwinds may all be explained by the theory, and whatever cause induces an up-moving current of air in a calm saturated condition of the atmosphere produces rain. Mackay in a letter describes how, in 1845, during a survey, he set fire to a patch of grass, and confined the flames to it. Soon a refreshing breeze sprang up, and a refreshing shower occurred. Capt. A. Mackay afterwards observed that he noticed the formation of a cloud at the apex of the smoke, and said it suggested Espy's theory to him. Accordingly it was determined to put the idea to the test. During a period of unusual heat and dryness, and on a cloudless day, we (states Mackay) told the (*Page* 170) negroes we could bring rain. We set fire to the grass. As the smoky column broke the cloud began to form. Then it thundered, and the cloud spread, and the rain descended in torrents, though the clear sky could be seen in all directions under the cloud. We often fired the sawgrass marshes, and whenever there was no wind stirring we were sure to get a shower; if there was wind there would be the appearance of rain on the horizon. Mr. A. H. Jones says he has performed similar experiments with success, and farmers in the dry season frequently fire the grass in order to get rain. By means of a nepheloscope Espy made experiments on the degree of cold produced, both in dry air and in moist, by sudden expansion from diminished pressure. He found that air in contact with water in a closed vessel will not saturate itself with water, or if saturated will cease to be so after a few days; that vapour permeates air from a high to a low dew-point with extreme slowness, if indeed it (*Page* 171) permeates at all; and that vapour rises into the regions where clouds are formed only by being raised up by ascending currents of air containing it. The manner in which up-moving currents of air carry vapour with them may be seen in the formation of cumuli during a hot summer's day, when the summits increase by the addition of thin films of cloud, produced by the air immediately above, the cloud being pushed up, and the cold of expansion from diminished pressure causing its temperature to sink below its own dew-point. Dissolving clouds frequently occasion strong winds at the surface of the earth; they are termed wind-clouds by the farmers in America. The air on the outer body of the trade winds is remarkably dry, and thus to some extent contribute to the greater height of the barometer there. The upper trade at the equator carries very little vapour in it, as, before it rises over the equatorial regions to one-third of the height of the atmosphere, nearly all its vapour is condensed into clouds, and therefore, when it rises above the clouds and rolls off to higher latitudes, it carries with it but little vapour. In short, the air does not carry so much vapour to high latitudes as the air below to the low latitudes, and when it descends to the surface it (*Page* 172) appears very dry, as its capacity for vapour is greatly increased by the heat of compression. Cloud is never formed except in an up-moving current, for air coming downwards always becomes drier; and if it be supposed that cold air in the same horizontal level should mingle with warm so as to produce condensation of vapour, the evolution of caloric in this air would immediately diminish its specific gravity, and it would begin to ascend. Wherever there is an up-moving column of air sufficient to form a large cloud, there is of necessity a down-moving current of air all round it; and where this current reaches, it is clear, if any clouds existed at first, they are soon dissolved by the heat of compression. Were it not for this cause there are large regions of the torrid zone which would be covered with eternal cloud.

Proc. Brit. Meteor. Soc., vol. i. 1863. (No. 3, for March 1862.) (*rv.*)

(*Page* 182.) The object of Glaisher's balloon ascent from Wolverhampton on March 22, 1862, was to determine the distribution of moisture throughout the atmosphere, but the balloon failed.

1863.

Airy, J. B. *Proc. Brit. Meteor. Soc.*, vol. i. 1863. (No. 8, for June 17.) (*rv.*)

(*Page* 365.) Bloxam does not seem to have fixed his attention on the supposed error Lamont endeavoured to correct. I apprehend Dalton's experiments amount to this: "In a limited space, of such a form as is very favourable to the motion of masses or particles of gas, the dry air and the aqueous vapour exist through the whole space, each exerting the same elastic pressure as if the other was not there." In ordinary (*Page* 366) quotation this law has been cited to some such effect as the following:— "In any spaces we may consider separately the law of distribution of vapour as that of an elastic gas, supposing no air present; and the law of distribution of air as that of an elastic gas, supposing no vapour present; and we may represent the actual state by combining these two gases in the densities thus indicated." For instance, the hygrometer shows a great density of vapour near the ground. It has been supposed that the density of vapour in every stratum above it can be computed from that lower density by the same laws as if vapour were the only gas above the ground, disseminating itself by the ordinary laws of gaseous dissemination. I do not know that any one has stated the principle so broadly; some have come near it, and I have no doubt it is the latent idea which guides many meteorologists. It is against this idea of dissemination that Lamont's experiments are directed. He does not dispute that where air and vapour are mixed Dalton's law holds truly, but he shows that the dissemination does not at all take place according to the law of simple elastic gases. A gas, if no other gas were present, would with great rapidity disseminate itself into every chamber connected with the place where it is set free. Aqueous vapour, there is no doubt, would do so if it were alone; but aqueous vapour combined with air will long remain in one place, as if the mixture of vapour and air produced viscosity. This is what Dr. Lamont shows.

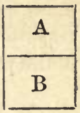
Blake, H. W. *Proc. Brit. Meteor. Soc.*, vol. i. 1863. (No. 7, for March 18.) (*rv.*)

(*Page* 331.) Describes cirri seen near Welwyn, Herefordshire, on Dec. 14, 1862, which presented auroral appearances after dark. Coupling this with Glaisher's observa- (*Page* 332) tions on the great height of cirri, he suggests that we must look for some other cause for their formation than that of aqueous vapour, especially when the dryness and the extremely low dew-point of those regions are likewise considered. [He implies that cirri may be simply auroras as seen by daylight.]

Bloxam, J. C. *Proc. Brit. Meteor. Soc.*, vol. i. 1863. (No. 7, March 18, 1863.) (*rv.*)

(*Page* 324.) In discussing the occurrence of the black-thorn winter in spring, he concludes that it is not due to any retrogression in the temperature. We must then seek for some other peculiarity that will serve to account for the sensible character of the season. [He does not say to what place his observations refer, but I presume it is Newport or some place in England. The general principle underlying the figures and discussion is of wide application.] What is the hygrometric state of the air? The mean temperature of the dew-point for the year, which is 43°, occurs on May 12; the mean value for April is 38°·6, that for May 44°, and the value for April 21 is 38°·9. The daily rate of increase for April is 0°·09, and that for May 0°·23—the mean rate from lowest to highest being 0°·12. On April 21 the dew-point temperature has risen 25 per cent. of its total annual rise, but the atmospheric temperature has risen at the same date 39 per cent. On April 21 the humidity is at its minimum value for the year, viz., 71·1. This is the essential fact which solves the problem; the 21st of April differs from every other day in the year in this respect, and the black-thorn winter reaches its

culminating point on this date; the evaporation produced by this low degree of humidity gives rise to that peculiar feeling of cold which characterises the season. But this excessive evaporation depends as much upon the high temperature of the atmosphere as upon the low temperature of the dew-point. The sky is far more clear of cloud than on the average, but it is not at its minimum; the lowest value for this particular is 6·0 on (*Page* 325) Sept. 4. The heat from the sun's rays at this period of the year is great, owing to the transparency of the atmosphere and the clearness of the sky; this perhaps renders the sense of coldness the more conspicuous and distressing. The low value for humidity is thus shown to be the dominating characteristic of the equinoctial winter. At this season of the year a great advance is observable in temperature, and the peculiarity of the season is explained by the fact that it is the period of the year in which the temperature rises to its highest point with an arctic atmosphere; the temperature continues to rise subsequently as the north declination of the sun increases, but this progress in the sun's position brings to our latitude in the temperate zone a moist as well as warm tropical atmosphere. The tendency in the atmosphere to flow from the north-east quarter is at its maximum intensity on April 19. At the period of the year which is under review the source from which our atmosphere proceeds is a region of ice, in which the temperature had been much below the freezing-point for months, and the vapour of its atmosphere is reduced to its lowest amount prior to its (*Page* 326) flowing to the lower latitudes. Similarly, as regards the St. Martin's summer the peculiarity of the season is evidently due to some other element than temperature. Dec. 3 is marked as having the maximum humidity for the year. On Nov. 9 the value is 82·6, and this may be regarded as the day on which the equinoctial or St. Martin's summer culminates, because the humidity attains a high and a maximum value on that day. Excessive humidity and consequent defective evaporation are the cause of the sensible warmth which attracts attention. The south-west wind has the ascendant during the season. The amount of cloud is great during the season, though not at the maximum. The high value for humidity is assuredly the essential meteorological characteristic of the equinoctial summer, and this high value seems to be brought about in a great measure by the rapid decline of temperature. May the low temperature of the atmosphere and the comparatively high temperature of the dew-point be explained by the fact that the atmosphere proceeds from higher latitudes than it does during our summer, and from cold land districts; but whilst crossing the Atlantic it takes (*Page* 362) up a large quantity of vapour? (No. 8, for June 17.) Lamont's article does not afford a definite decision as to the relation of the atmospheric aqueous vapour to the air. The aqueous vapour probably does not form an atmosphere totally independent of, nor absolutely dependent upon, the air; the vapour is probably not merely mechanically mixed with the air; it is probably not chemically combined with the air; the connection subsisting between vapour and air, as the two exist together in the atmosphere, may be dependent upon electric conditions. Neither Dalton's theory nor Lamont's theory asserts either the positive or the negative view of either of the propositions absolutely. It is to be remembered that Dalton's theory is not merely a theory; the laws he announced are laws deduced from and clearly indicated by experiment carefully conducted; and he deals with the physical results of the combination rather than the law by which the combination is effected. No one perhaps will at present venture to pronounce on the essential nature of the combination. Professor Lamont's experiments rather confirm the three principal results deduced from Dalton's experiments. "As to the mutual relations subsisting between vapour and air, when they are simultaneously present, the experiments (of Dalton) afford no information." This is, perhaps, not quite a correct statement; but what are the mutual relations indicated by the professor's experiments? They seem to be nothing more than this:—If the portion A of the space AB is occupied with air, and the portion B with vapour, whatever the elastic force of the air may be under this arrangement, the amount of that force will be diminished by withdrawing the



(*Page* 363) vapour from B, and allowing the same air to occupy the whole of the space AB. The interpretation that Dalton gives to the second of the three propositions is that when air and vapour are mixed together in the manner (though perhaps not in the same degree) that obtains in the atmosphere, neither of the two influences the elastic force of the other, or, more correctly, this is the result obtained by experiment. He gives no such interpretation as that "no mutual relation whatever existed between vapour and air;" he would doubtless have acknowledged such mutual relation as the diagram above refers to. Dalton's theory does not imply that the atmospheric vapour *is* sustained in equilibrium by itself alone, but that it *can* attain to a state of equilibrium by virtue of its gravity only; and its tendency to acquire equilibrium as an independent agent helps to determine its movements and to regulate its quantity in any particular locality. The third proposition properly declares that there is indeed always a tendency to a normal relation "in so far as that each of the constituents has always a normal (though constantly varying) condition belonging to it; but this does not ignore the fact that neither the normal condition nor the normal relation can ever be reached, owing to the law that one of the two bodies is being perpetually exhausted at one point and reproduced at another, which necessarily leads to this one being always in motion and never in equilibrium. It may be strictly true, or it may be true in a limited sense, that "a mass of vapour and a mass of air placed in communication with each other mutually preserve a state of equilibrium without the vapour penetrating into the air or the air into the vapour"; but this is not contradictory to Dalton's theory. Dalton states that the two constituents do not readily mix spontaneously; the professor contrives artificial means to counteract the natural tendency to mixing; but Dalton's theory does not gainsay the possibility of doing this. Dalton's theory is not adverse to the proposition that if air be preserved unmixed in the space A, and vapour be preserved in the space B, the elastic forces of these two bodies will press one upon the other. It is quite clear that whilst each maintains its own separate position, each must press (*Page* 364) against the other where they come in contact. According to Dalton, if as much vapour be forced into a limited space as can exist in that space in the form of vapour, the quantity that can so exist will not be diminished by forcing air into the same space with the vapour, provided the two be intermixed in the manner they admit of. Lamont's experiments or reasoning are not opposed to this. If vapour is slow in diffusing itself through the air, and a portion consequently remains unmixed, this portion will then be subjected to the pressure of the air, and it may then be condensed, although it could not have been so condensed by its own pressure. A mass or layer of vapour may be imagined as held in the grasp, as it were, of the atmosphere, and it would then comport itself the same as if it were enclosed in an elastic bag; it would be subjected to the pressure of the atmosphere. It is probable that masses of vapour (*Page* 365) often exist in the midst of the atmosphere mixed with a comparatively small proportion of air; it would then not press upon the atmospheric vapour beneath in the same manner that it would do if diffused equally through the atmosphere; it would press against the surrounding atmosphere, and the atmosphere would not press upon it. The vapour pressure thus transmitted through the atmosphere would not be distinguishable at the surface of the earth from the air pressure; we should not be able to detect the vapour existing in this state by any of our instrumental aids at the surface of the earth. The Dalton law is correct, but a false interpretation has been given to it by the invention of hygrometers. The hygrometer detects that portion of the vapour pressure only which arises from the vapour diffused through the air; and the quantity of vapour in the air is probably always greater than the vapour pressure indicates; the air pressure must be to the same extent at least less than the estimate. This may lead to the conclusion that the atmospheric vapour is a more powerful agent in giving motion to the atmosphere than it has hitherto been supposed to be. Pure

vapour in the midst of air is subjected to foreign pressure, and it is not governed by its own laws; if it be mixed with a comparatively small proportion of air it will be placed more or less in the same predicament. If it has expanded itself fully through the texture of the air it will then be subject to its own laws; the pressure it then exercises is the pressure of itself, and of the whole of itself.

Scientific Union.

The rapid progress of science now going on is, in part, the result of the great increase in the number of workers. This is accompanied by a larger and larger host of scientific serials. The consequence is that the student finds an increasing difficulty in ascertaining what has been done, or is in process of being accomplished, not only in his own special line of study, but also, and more particularly, in such as do not immediately interest him. Every student finds, from time to time, that he has a desire for full information on subjects in these outlying sciences, for the purpose of throwing light upon his special studies. The state of literature is such that he is frequently daunted by the difficulties attending his research, or, if he perseveres, he finds a great deal of time unnecessarily wasted. The remedy for this is the focalisation of knowledge round a series of centres. The two main steps in the process are, first, collection, and, next, classification. It is with this ulterior object in view, that all persons interested in meteorology are earnestly asked to forward their names and addresses, particulars as to the work they have done in meteorological and other sciences, their present lines of study, ways in which help is desired, and any other items that may occur to them. These details will be classified, and, when the opportunity offers, selections from them will be published. The Conductor will exercise careful discretion in the selection, as also in the use he may make of the more private details. The first list will be published, if circumstances permit, in November, 1883; but correspondents are requested to send in answers soon, in order to allow of ample time for their classification, and for their utilisation in private correspondence in the interests of correspondents.

In order to prevent any misconception, it may be stated that the Conductor's object is solely to promote scientific union, and is no way intended to be of a charitable nature in any pecuniary sense. If there is a sufficient response to these requests, the same line of proceeding will hereafter be suggested, from time to time, for the students in other branches of science.

Newspapers and scientific journals of all countries, willing to help in this matter, are asked to make the above requests known to their readers.

Address, Conductor, 'Scientific Roll' office, 7 Red Lion Court, Fleet Street, London, E.C.

The above notice first appeared in August, 1882, and has been repeated in the subsequent numbers. As yet only a few individuals have complied with the request made. It is

only from individuals that reliable materials can be obtained; consequently, if no adequate response is made, no list of the kind proposed will be attempted.

Communications have been received from Prof. Robert B. Warder intimating that he is compiling a list of papers relating to the speed of chemical action, and the intensity of chemical affinities. There are many papers dealing with these subjects which are liable to be overlooked owing to the titles being of no assistance. All individuals who have made observations on the subjects mentioned would help Prof. Warder by communicating with him. He has two papers on the subject in No. 4 of the 'Scientific Proceedings of the Ohio Mechanics' Institute.' One is on 'A Criterion for Measurements of the Speed of Chemical Action'; and the second is a summary of 'Urech's Investigation of the Speed of Inversion of Cane Sugar.' Any chemist or physicist interested in this subject can have a copy of this number supplied to him gratis on applying to the "Publishing Committee, Ohio Mechanics' Institute, Cincinnati, Ohio, U.S.A." There is another reason why such persons should put themselves in communication with Prof. Warder through this committee, which is, that it will strengthen his hands to carry out an organised enquiry into the subject, should such an enquiry seem as practicable as it is desirable.

We have also recently received the earlier numbers of 'Science,' and take this opportunity of drawing attention to it, because it is, we believe, the first weekly periodical which has adopted the methodical arrangement which is advocated by the 'Scientific Roll.' As stated in the prospectus issued in No. 5, "this prominent feature will be particularly attractive to the specialist in whatever branch, as he will at once know where to look for the latest information about all the more important work in his own field of investigation." The reviews are severely critical, yet judicious and fair, being as unsparing in blame as in praise, when each seems deserved; the articles are of the highest quality; and the abstracts are compact and pointed, and are drawn up by specialists of high repute. We are glad to see that due prominence is given to the work performed by Government and other organisations, and would refer to the following paragraph as an example, which we hope will be followed in other countries and in other subjects. The paragraph is from No. 10, published on April 13, 1883, p. 291:—

Contagious Diseases of Animals—The subject of the prevention and cure of contagious diseases of animals has for many years been considered in this country. For a long time extirpation was resorted to, and with good results, notably in the work of the Commission appointed by the State of Massachusetts in 1860, which entirely succeeded in freeing that State of pleuro-pneumonia. Of late years inoculation or vaccination has been employed with such success abroad by Pasteur, that we are justified in anticipating most beneficial results from the prosecution of his methods in this country. Pasteur has been engaged in efforts to establish some law through the agency of which such diseases as pleuro-pneumonia, charbon, foot-and-mouth disease, and other diseases of domestic animals, could be controlled and cured. Dr. D. E. Salmon has been pursuing similar experiments under the direction of the U.S. Department of Agriculture, though necessarily in a more limited way, and has met with such success, that he has great faith in the result of the more elaborate and extensive experiments which he is about to undertake in the district of Columbia. Commissioner Loring has determined to place at the disposal of Dr. Salmon the necessary land, buildings, animals and apparatus to enable him to make the proper microscopical observations, and to carry on any experiments that will tend to establish some economical method by which our farmers or breeders may control the diseases of their animals. Dr. Salmon is of opinion that such diseases as Texas fever, charbon, and pleuro-pneumonia are the results of germs which he has found in his post-mortem examinations, and that it is possible to protect unaffected animals from these diseases by dilute inoculation.

The election of a recorder of economic entomology is another example which we trust will be soon followed in other counties. Mr. S. L. Mosley, Beaumont Park, Hudders-

field, is the recorder, and in the 'Naturalist' for May 1883, he appeals to all Yorkshire naturalists to help forward this desirable work by sending him notes or specimens, or both, of any kind of insect ravages which may come under their notice. He observes that he can do little without such help, and particularly solicits communications on all insects found to be injurious to field or garden crops, such as daddy-long-legs, turnip-flea, beetles, aphides, wireworms, larvæ of various kinds, &c.; also notes of any remedies which have been found serviceable, either artificial, as chemical dressings, or natural, as the counteraction of other insects, insectivorous birds, &c. Anyone so assisting will probably have any report that may be issued sent to him free. Part of the recorder's duty is to give advice upon the best known and most simple remedies to all applicants, who are requested to accompany their communications with specimens of the insects, as also with illustrations of the injury done by them.

The Scientific Enquirer.

Correspondence is invited on Science matters of all kinds. In all cases names and addresses should be given; but these will not be published without the writer's consent. The Conductor will not be responsible for the opinions expressed by correspondents. All communications should be addressed to the Conductor, 7, Red Lion Court, Fleet Street, London, E.C.

Replies to questions should be numbered in accordance with the questions to which they refer. The contractions following the questions and answers, indicate the class of notes to which they will ultimately be assigned, and the place where full reference will be given to the details bearing upon them. The following request and set of questions are reprinted from the circular sent us by Dr. Kellogg. The numbers in parentheses are those given in the original, those which precede them are those adopted for the 'Scientific Roll' for the purpose of reference.

H=Homo, or Man.

CIRCULAR OF INQUIRY BY A COMMITTEE CONCERNING DIPHTHERIA.

Office of the Michigan State Board of Health,
Lansing, Michigan, October, 1882.

DEAR SIR,—The undersigned, having been appointed a committee of the Michigan State Board of Health to prepare a paper setting forth what is known concerning Diphtheria, and wishing to make their data as complete as possible, respectfully invite your attention to the following questions, and ask that if you have made observations on any of the several points to which attention is directed, you will have the kindness to put the committee in possession of the facts observed, by answering, at your earliest convenience, such of the following questions as you may be able to answer. Facts, and so far as possible personal observations, constitute the kind of information which is considered the most desirable and useful. Those who have made observations which are not covered by the questions asked below, are also invited to communicate the same to the committee. Please address replies to this circular to John H. Kellogg, M.D., Battle Creek, Michigan; or to Conductor, 'Scientific Roll' Office, 7, Red Lion Court, Fleet Street, London, E.C.

174. (1.) Please state facts concerning instances of marked communication of Diphtheria by contagion. (H. 1)

175. (2.) Have you observed sporadic cases of Diphtheria which could not fairly be traced to any source of contagion? If so, please give full details concerning such case, stating also what efforts were made to discover a possible origin by contagion; what about visitors from or to other places; trunks, clothing, or other packages or articles received, &c.? (H. 2)

176. (3.) Please state in full the sanitary condition of the premises where each such sporadic case occurred. (H. 3)

177. (4.) At or shortly before the time you observed the sporadic cases, if you have observed any such, was Diphtheria present in the vicinity or in neighbouring districts? (H. 4)

178. (5.) If so, how were the "sporadic cases" situated with reference to the other cases, as regards direction of prevailing winds, lines of travel, &c.? (H. 5)

179. (6.) Have you observed severe and unmistakable cases of Diphtheria which were apparently contracted from cases so mild that they were not distinguished from ordinary sore throat or acute follicular pharyngitis? If so, please state in full the facts respecting each case. (H. 6)

180. (7.) Have you observed mild cases of Diphtheria to give rise to the disease in a severe or malignant form? (H. 7)

181. (8.) What were the sanitary conditions (such as water-supply, milk-supply, exposure to foul air, &c.) where, under your observation, mild cases of Diphtheria have given rise to severe cases of the disease? (H. 8)

182. (9.) Have you observed any cases of the disease in domestic or other animals? (H. 9)

183. (10.) If you have observed the disease in animals, please state how it was communicated to them, whether from human beings or from other animals. (H. 10)

184. (11.) Have you observed cases in which the disease was communicated to human beings by domestic or other animals. (H. 11)

185. (12.) Please state results of any observations as to the communication of Diphtheria by other discharges than the sputum, as the fecal or vesical discharges, or by the breath, or other emanations from the body. (H. 12)

186. (13.) Please state all facts within your observation which point to the contamination of the water-supply as a probable means of communicating Diphtheria. (H. 13)

187. (14.) Please state facts within your observation which point to contaminated water-supply as a probable origin of Diphtheria. (H. 14)

188. (15.) If you have observed any such facts, please state what was the probable source of contamination of the water. (H. 15)

189. (16.) Please state the facts concerning each case observed by you in which Diphtheria was communicated by means of milk. (H. 16)

190. (17.) What other sources of contagion have you observed, if any? Please state facts concerning each case. (H. 17)

191. (18.) How long have you known the contagium of Diphtheria to retain its power of infection when confined, as in clothing or bedding, &c., hung in a closet or packed away in a trunk? (H. 18)

192. (19.) How long have you known the contagium of Diphtheria to retain its power of infection when exposed freely to the action of the air, as in the walls of a house? (H. 19)

193. (20.) Have you known Diphtheria to reappear, without a new importation of contagious matter, in a house which was suppossd to be thoroughly disinfected? If so, state what disinfectants were used and describe carefully the mode of application. (H. 20)

194. (21.) Please describe methods of disinfection employed in undoubted cases where the disease did not reappear. (H. 21)

195. (22.) Have you observed cases in which the local symptoms of Diphtheria were so slight that it could scarcely be distinguished from a common sore throat? (H. 22)

196. (23.) What symptoms or physical signs do you regard as characteristic of Diphtheria? (H. 23)

197. (24.) Have you observed cases in which there was no local expression of the disease in the throat? (H. 24)

198. (25.) Have you observed cases in which the nervous symptoms alone were present? (H. 25)

199. (26.) What course do you advise in the interests of public safety respecting the management of a case of suspected Diphtheria, when you are in doubt whether it be a genuine case of Diphtheria? (H. 26)

200. (27.) Please give facts as to relapses, particularly relating to cases in which the relapse was a considerable time after apparent convalescence or recovery. (H. 27)

201. (28.) Have you ever observed the occurrence of undoubted Diphtheria a second time in the same person? (H. 28)

202. (29.) If so, please state the length of time which elapsed between the attacks. (H. 29)

203. (30.) Please state all facts under your observation relative to the occurrence of Diphtheria a second time in the same person. (H. 30.)

204. (31.) Under your observation, what proportion of persons who escape on full exposure to Diphtheria have previously had the disease? (H. 31)

205. (32.) Please state all the facts (relative to age, intervals between attacks, severity of previous attack, other exposures, &c.) as to previous attacks of Diphtheria, concerning persons whom you have observed to escape the disease when fully exposed. (H. 32)

206. (33.) Please state all other facts, under your observation, relative to immunity from Diphtheria among persons apparently exposed to the disease. (H. 33)

207. (34.) What proportion of the *mild* cases of Diphtheria observed by you have been of persons under ten years of age? (H. 34)

208. (35.) What proportion of the *severe* cases of Diphtheria observed by you have been of persons under ten years of age? (H. 35)

209. (36.) What proportion of the cases of Diphtheria observed by you in persons aged *under* ten years have proved fatal? (H. 36)

210. (37.) What proportion of the cases of Diphtheria observed by you in persons aged *over* ten years have proved fatal? (H. 37)

JOHN H. KELLOGG, M.D.
JOHN AVERY, M.D. } *Committee.*

ANNOUNCEMENTS.

Part III. of the 'Scientific Roll' will be commenced, if life and health be granted to the Conductor, as soon as a sufficient number of subscribers' names have been received. It will comprise the whole of Vol. II. of the 'Scientific Roll,' and will be issued to subscribers at home for 7*s.* 6*d.*, and to those abroad for 10*s.* In order that the Bibliography may be as full as possible, authors and publishers are respectfully solicited to send copies of, or references to, all their publications dealing with the barometrical condition of the air.

As soon as 200 persons have expressed a wish to subscribe for any one of the subjects mentioned below, the publication of that section of the 'Scientific Roll' will be forthwith commenced. The subscription price will be 7*s.* 6*d.* and 10*s.* for each volume, according as the residence of the subscriber is at home or abroad. Each volume will contain about 400 pages; and each volume will, in most cases, contain two or more parts, each of which may be subscribed for separately. The extent of these parts will depend upon the amount of matter in hand, so that the subscription price cannot be fixed at present, but will be decided upon when the publication of each part is commenced. The following is a list of the principal subjects:—

Atmosphere, Water, Ocean (5), Rivers, Lakes, Springs, Floods, Glaciers, Land, Elevation and Subsidence of Land and Sea-Bottom, Denudation, Orography, Earthquakes, Volcanoes, Earth Magnetism, Terrestrial Heat, Marshes, Minerals, Stratigraphy, Rocks, Plants generally and in classified groups; Animals generally; Protozoa, Actinozoa, Hydrozoa, Echinodermata, Crustacea, Scolecida, Annelida, Mollusca, Myriapoda, Arachnida, Rhynchota, Orthoptera, Diptera, Coleoptera, Lepidoptera, Neuroptera, Hymenoptera, Pisces, Amphibia, Reptilia, Aves, Mammalia, and Man.

Subscribers' names only are asked for now. The sending of these will not involve any pecuniary liability, but will simply be taken as implying that the senders take an interest in the work, and will probably undertake to subscribe when asked to do so. At the moment of going to press the subject for which the largest number of names has been received is Ocean.

The Conductor is very desirous of continuing the publication of his work, but he is both unwilling and unable to do so if such continuance involves a pecuniary loss. He has no desire to claim any merit for what he has done beyond what he may deserve, and as some guarantee that he is able to perform what he undertakes to do, he would refer to the eleven numbers of the 'Scientific Roll' now published. If it is considered that such a work will be of any advantage to scientific research, it is to be hoped the requisite support will not be withheld until it is too late; if the work is useless or radically defective, then the sooner it is terminated the better. It seems certain, however, that if not called for now, a work conducted upon a similar plan will be called for before many years have passed. In all probability the prosecution of the task will then be more difficult and more expensive. In the present state of the case a few hundred subscribers only will suffice to establish the work on a safe basis, and allow of a quicker publication.

Lamont, Prof. *Proc. Brit. Meteor. Soc.*, vol. i. (No. 6, published Jan. 21, 1863.) Translated by W. T. Lynn. From *Phil. Mag.*, Nov. 1862 (*rv*).

(*Page* 311.) We are now arrived at a point in meteorology where it is absolutely necessary to come to a definite decision as to what is the relation in which the aqueous vapour existing in the atmosphere stands to the atmosphere itself. Does the aqueous vapour form an atmosphere itself, independent of the air; or is it merely mechanically mixed with the air, so as only, as a gas standing in mechanical relation to the air, to increase the volume and the weight of the atmosphere? I think I have arrived at a decisive result—one which is opposed to the generally prevailing views of physical geographers and meteorologists. Nothing of importance has been added to Dalton's theory of the action of aqueous vapour by later investigators. Dalton's experiments tend to the following results:—1. In space destitute of air the evaporation of water goes on only until the vapour has attained a determinate expansive force, dependent on the temperature; so that in every space void of air which is saturated with vapour a determinate vapour pressure corresponds to a determinate temperature. 2. In space filled with air the same (*Page* 312) amount of water evaporates as in space destitute of air; and precisely the same relation subsists between the temperature and the expansive force, whether the space contains air or not. 3. The evaporation of water goes on rapidly in space devoid of air, but very slowly in space filled with air in a state of quiescence; and even when it is assisted by a tolerably brisk motion of the air a considerable time is notwithstanding always required. In this way are the development and extent of aqueous vapour, in space void of air and space filled with air, determined by means of Dalton's experiments; as to the mutual relations subsisting between vapour and air, when they are simultaneously present in the same space, the experiments afford no information; and this deficiency Dalton supplied by giving to the second of the above-quoted propositions such an interpretation as if no mutual relations existed between vapour and air, and as if they remained near each other without producing the slightest mechanical effect upon one another. It is strange that philosophers have accepted this theory without remarking that it constitutes only a possible result of the experiments; and that meteorologists have treated it as available for application to the aqueous vapour of the atmosphere, and have supposed an atmosphere of vapour to exist independent of the air, notwithstanding that the third of the above propositions properly declares that there is indeed always a tendency to a normal relation, which is conceived to be in a state of restoration, but which is never reached, because, in consequence of the changes constantly taking place, the requisite time to produce an equalisation is never afforded. Objections have from time to time been brought forward to the existence of an atmosphere of vapour independently subsisting. Bessel has ('Astr. Nachr.,' No. 236) adduced the consideration that in such a vapour atmosphere the expansive force of the strata incumbent upon one another must diminish according to a certain proportion, but that from different observations it may be concluded that this proportion does not really exist. The experiments of Broun in Makerstoun (Report to Sir T. Brisbane) and Jelinek in Prague ('Denk. Wien. Akad.,' vol. ii.) proved that in different localities situated very near together, where the same reading of the barometer is observed, a very different vapour-pressure may be indicated. Espy opposed the theory, and exposed its defects, without furnishing a precise refutation. I believe I first brought forward a proof of its incorrectness in 1857, when I showed (*Page* 313) by means of observations extending through many years, that in a small vapour-pressure the mean reading of the barometer stands quite as high as in a great vapour-pressure; at the same time I contrived an easily-performed experiment in which, contrary to Dalton's theory, a mass of vapour and a mass of air placed in communication with each other mutually preserve a state of equilibrium without

the vapour penetrating into the air or the air into the vapour. As the result of this I laid down the proposition that the vapour exerts a pressure upon the air and the air upon the vapour; and that the atmosphere is to be regarded as a mixture of masses of air, some more and some less humid. Strachey furnished a second very strong proof of the inadmissibility of Dalton's theory in a paper read to the Royal Society in 1861. Proceeding upon considerations which are fundamentally identical with those developed by Bessel, he gave a collection of the results of observations which had been obtained upon high mountains and in air balloon expeditions, and showed that they were incompatible with the supposition of an independently subsisting atmosphere of vapour. To instance one point only, it may be here mentioned that the observations of Walsh, who ascended in a balloon to the height of 23,000 feet, place us in a position to calculate the pressure which the vapour contained in the atmosphere would exert upon the earth's surface; but the value determined in this manner amounts only to the fourth part of the pressure actually assigned by the psychrometer. Nevertheless we find in the most recent times that the pressure of the dry air and the pressure of the vapour atmosphere are kept distinct. The only way of removing the rooted ideas based on Dalton's laws is to prove that these laws themselves contain an essential error. Air and vapour spread into each other with extreme slowness; it is mainly the circulation of air that carries off the vapour from the evaporating surface; one would almost believe that the individual molecule of air must come to the surface of the water to take thence the moisture, and to the chloride of calcium to give up to it the moisture; the expansive force of the vapour itself is in every case a matter of small influence on its diffusion in the air. Now, if we take a closed tube ABCD, fig. 1, filled with air, and introduce a small quantity of water through an aperture near A, which is immediately afterwards closed, into the bottom AB of the tube, the water begins gradually to evaporate, and the vapour ascends after the expiration of a certain time up to *ab*. How then will the pressure be distributed upon the interior sides of the tubes? If the vapour and air exert a mutual pressure upon one another, the expansive forces of the air and of the vapour will act together in such a manner that an amount equal to their sum will press upon all points of the interior wall; and if we take separately the pressure peculiar to the vapour alone, it is precisely as great as if the mass of vapour was uniformly distributed in the whole space ABCD. A totally different state of things will result if the view set up by Dalton is well founded; for as, according to this view, the vapour diffuses itself in the interstices of the molecules of air without producing any mechanical effect upon the molecules themselves, no pressure at all can be produced upon the interior side of the tube by the expansive force of the vapour under the circumstances indicated above, and no pressure takes place until the vapour reaches the upper surface CD. The state of things here indicated is only a transitory one; a similar state may, however, be made permanent by maintaining in the lower space AB*ab* a higher and in the upper space *ab*CD a lower temperature. If we denote the lower space by V, the upper by V′, the lower temperature by t, the higher by t', and the corresponding expansive forces of the vapour by $f(t)$ and $f(t')$; also the expansive forces of the enclosed masses of air by $k(1+at)$ and $k(1+at')$, we have, according to the hypothesis advocated by me, the expansive force of the mixture

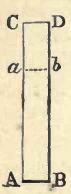


Fig. 1.

$$=\frac{V}{V+V}\Big[k(1+at)+f(t)\Big]+\frac{V'}{V+V'}\Big[k(1+at')+f(t')\Big]$$

$$=k+\frac{ka}{V+V'}\left(Vt+V't'+\frac{1}{V+V'}(Vf(t)+V'f(t'))\right);$$

whereas, according to Dalton's theory the expansive force will only amount to

$$k+\frac{ka}{V+V'}(Vt+Vt')+f(t');$$

while the vapour passing into the space *ab*CD with the force $(t) + f(t)$ must be immediately condensed. Thence it immediately follows that if the temperature t' of the upper space remains constant, while the temperature of the lower space gradually increases, the pressure upon the upper surface CD is increased, according to Dalton's theory, only by the expansion of the air, but not by the newly forming vapour itself; whereas, according to my hypothesis, besides the effect which is produced by the expansion of the air, a very considerable augmen- (*Page* 315) tation of the pressure arises from the newly-formed vapour. As we can imitate these conditions, we have a simple means of deciding as to the correctness of Dalton's theory. I selected the following experiment:—A glass tube, bent in the form represented in Fig. 2, was provided at one end with a globe K, whilst the other end *e* was left open; in the straight part *de* it was made to contain a drop of quicksilver *q*. The curved part *ckd* of the tube was plunged into a vessel BB filled with clear water; into the vessel AA, where the globe K was placed, cold and warm water could be poured. The globe K was first filled with dry air, and the experiment showed that if the temperature was increased from 67°·3 to 126° the drop of quicksilver moved forwards by 12·224 in. During this experiment a thermometer placed in the vessel BB stood at 59°. Afterwards the globe was opened by breaking off the fine point *a*, some water introduced, and the point again joined on by melting. Again cold and warm water

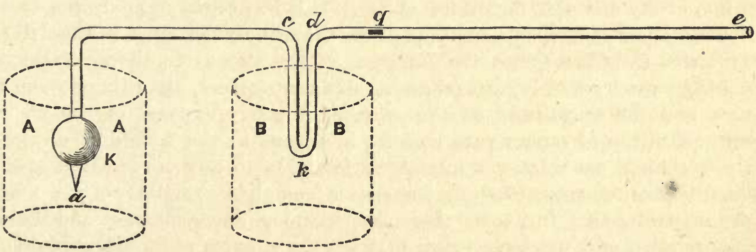


Fig. 2.

were poured into the vessel AA, while the temperature of the tube remained unaltered, by which means, according to the theory of Dalton, a rise of temperature from 67°·3 to 126° would, if the vapour had not penetrated in the tube up to the drop of quicksilver, move the latter, as before, 12·224 in., and if the vapour had so penetrated, at the most $\frac{1}{18}$th further; instead of which the motion actually produced amounted to nearly the double of this. It resulted from accurate measurement that the 12·224 in. were passed over as soon as the temperature had been raised from 67°·3 to 101°·5. A second glass tube was employed of a similar form, but with a smaller globe, and with this, as long as there was only dry air in the globe, an increase of temperature from 64°·4 to 131°·5 occasioned in the drop of quicksilver a motion of 13·706 in.; but after a small quantity of water had been introduced into the globe, the quicksilver moved the same distance when the temperature was raised only from 64°·4 to 102°. As it might be imagined that it was possible that after a longer interval of time the vapour would extend up to the drop of quicksilver and then produce (*Page* 316) a different result, the globe was left for a whole hour in warm water, but the position of the water remained unchanged. Also, after the termination of the experiment, neither in the first nor in the second tube could a trace be perceived of the vapour having passed down into the bent part between *c* and *d*, so that it probably penetrated into the tubes not at all, or only to a small extent.

On this supposition the observed effect would require the conclusion that the increase in the expansive force of the dry air in a change of temperature from 67°·3 to 126° is precisely as great as the increase in the expansive force of the air and the aqueous vapour in a change of temperature from 67°·3 to 101°·5; and this also agrees exactly, for the former increase is calculated to be ·119, and the latter amounts to—

For the air	0·070
For the vapour	0·048
Therefore, together	0·118

In the second experiment we have the increase of the expansive force—

For dry air from 64°·4 to 131°·5	0·076
For vapour „ „	0·052
Therefore, together	0·128

little differing from the preceding number. I repeated the experiment in a modified (*Page* 317) form, calculated to give more accuracy. The result was substantially the same. The conclusion is, that the air exerts a pressure upon the vapour, and the vapour upon the air. I hope at a future opportunity to show that the humidity must be regarded as adhering to the molecules of air, and that the phenomena admit of a simple explanation by means of a natural hypothesis concerning the expansion of dry and wet molecules of air. If it be desired to apply the above to the circumstances of the aqueous vapour in the atmosphere, it is in the first place to be inferred from that (since the diffusion of the vapour in the air takes place (*Page* 318) but very slowly, and since in different places, according to the temperature and the magnitude of the surface of water exposed to the air, very different quantities of vapour pass into it), in regard to the humidity of the air, strictly speaking, no relations subsist conformable to any law. Of course the continually existing currents of air occasion a complete mingling of the more or less dry masses of air; but this takes place in no uniform manner, and therefore no exact relation of dependence exists between the degrees of humidity in different points of any space. But particularly the idea of an atmosphere of vapour subsisting independently by itself appears to be inadmissible, and the data furnished by the psychrometer can no longer be regarded in any other light than as the expression of local humidity.

Speke, J. H. *Journ. Roy. Geog. Soc.*, vol. xxxiii. (1863) (*rs*).

(*Page* 333.) In Africa, beyond 3° lat. both north and south, the land is subject to continual droughts for five, six, or more months in the year, which last systematically longer as the distance increases from the equatorial zone. The rain follows the sun, and the opposite region is dry.

1864.

Buchan, A. (*B.* 1864, 1.)

Monthly means will not serve for ascertaining when are the periods the clouds begin to disperse and when brighter skies take their place. In Scotland [and no (*Page* 9) doubt in other places under like conditions] the highest temperature occurs in the broad plains, particularly those which are bounded on the south-west by high and extensive ranges of hills, which by more effectually draining the south-west winds of their moisture, clear the skies of clouds, and thus allow freer passage to (*Page* 137) the sun's rays. When the air is clear and transparent, but loaded with much moisture in an invisible state—in other words, when the dew-point is high—the invisible particles of water offer a powerful obstruction to the free passage of the caloric of radiation, in much the same way as stones in the channel of a river oppose

its course; so that in a moist though perfectly clear atmosphere the process of radiation proceeds at a very slow rate. Let, on the contrary, all or nearly all the vapour be drained out of the air, the escape of heat from the earth's surface by radiation would then be so swift and great that the temperature would fall low (*Page* 149) enough to destroy life. For turnips the weather should be mild and dry, during the middle of May [Scotland being the country specially alluded to] to the middle of June, when they are sown; moisture and warmth are required in their brairding, and their growth towards the time for singling. At singling and after-growth the weather should be dry and warm. These include the second half of June and most of July. From July to October the weather should be showery at intervals. For cereals, the sowing month of March for oats, and April and half of May for barley, should be cool and dry. In the after-growth of wheat, barley, and oats, till the blooming season in July, the weather should be dropping and warm. The blooming season in July should be dry, warm, and calm. After that, till within a month of harvest, at the end of August or beginning of September, there should be showers and warmth. During the period from that to and after harvest it should be dry and hot.

1865.

Becquerel, A. C. (*B.* 1865, 1.)

[The name is misprinted Becqueral in the place cited. The paper is translated from 'Comptes Rendus,' lx. p. 136.] The influence of forests on climate depends (*Page* 235) in part on the process of evaporation possessed by the leaves. Evaporation from the leaves is a constant and active cause of humidity, which a little lowering of the temperature condenses into vapour [as the translation has it]; and the water which is thus produced tends to keep the soil moist. The effect which the (*Page* 236) cutting down of forests has on the sources and volumes of the rivers which water a country is too important an element to be lost sight of. The difficulty of discovering the causes of these effects is sometimes so great that we could not predict whether a particular spring or river would be increased by cutting down a forest and bringing the soil under cultivation. Forests contribute to the sources, not only by the humidity they cause and the condensation of vapour which accompanies it, but also by the obstruction they offer to evaporation from the soil; and it may be remarked that the roots of the trees, by breaking up the soil, render it more (*Page* 237) porous, and thus facilitate the process of infiltration. In considering the important question of the influence which the cutting down of woods has on springs and rivers we arrive at the following conclusions:—1. Extensive clearings of wood lessen the volume of the rivers which water a country. We are not yet able to decide if this diminution is to be attributed to a less quantity of rain falling annually or to a more active evaporation, to both causes combined, or to a different distribution of the rainfall. 2. Cultivation carried on in a dry and rainless region lessens the amount of spring-water. 3. In countries which have not undergone any change in the amount of land under cultivation the quantity of spring-water appears to be always the same. 4. Forests, in the better protection they afford to springs, husband the water and regulate its flow. 5. The humidity is increased by forests, and the roots of trees render the soil more pervious to the rain-water. 6. Clearings in mountainous countries exercise an influence on the sources of the water supply and on the rivers.

Buchan, A. (*B.* 1865, 4.)

(*Page* 200.) From the observations collected [on the storms of Europe towards the end of 1863] we learn that as long as the barometer did not fall below the mean there was no continuous rain anywhere; but blue sky, varied with sky partially clouded or with fog, prevailed. When, however, the barometer fell in the

west, the sky began to be obscured and showers to fall at intervals. When the centre of the storm had passed, or the barometer had begun to rise, the rain became less heavy, the clouds began to break up, and fine weather, ushered in with (*Page* 228) cold breezes, ultimately prevailed. Oats require a lower temperature (*Page* 229) and more moisture to bring them to perfection than wheat or barley. (*Page* 230) The greatest number of victims to consumption [in Scotland in 1864], and perhaps also brain diseases, occur in spring, when the air is driest; and the least number in October and November, when the humidity of the air is greatest.

Forbes, C. *Journ. Roy. Geog. Soc.*, vol. xxxiv. (1865) (*rsp*).

(*Page* 157.) In Vancouver Island the ordinary course of the seasons is as follows. After the gales with rain, which generally mark the period of the equinox, fine clear weather sets in, and continues till about the middle of November. Then the rains set in.

Palgrave, W. G. *Journ. Roy. Geog. Soc.*, vol. xxxiv. (1865) (*rsp*).

(*Page* 136.) In the Nejed between March and November the fine weather is uniformly clear and dry.

Watts, H. (*B.* 1865, 14.)

(*Page* 100.) The action of the sun upon the water at the surface of the earth causes a natural process of distillation upon an enormous scale to be always going on. The water evaporated from the earth's surface rises in the air as vapour, and being afterwards deprived of its heat of vaporization, partly by radiation into space, and partly by contact with mountain-summits or with the cold air existing at high elevations, returns to the earth in the various forms of dew, mist, rain, snow, hail, etc. In this way an immense quantity of water is being continually lifted from the sea-level, a large portion of which does not fall again directly into the sea, but being deposited on elevated portions of the land, becomes the mechanical source whence rivers and streams are supplied. The watery vapour which reaches the higher and colder regions of the atmosphere is there condensed into snow. This, as it falls again towards the earth, returns to the condition of water, if the air is sufficiently warm to liquefy it; but part of it reaches the earth unmelted, and that which falls upon regions whose temperature is below 0° C. accumulates to form the masses of ice known as glaciers.

1866.

Buchan, A. (*B.* 1866, 2.)

(*Page* 352.) [Since the bibliography was published the facts have been entered from an earlier source, so that this bibliographical reference should be cancelled.]

Home, D. Milne. (*B.* 1866, 5.)

(*Page* 330.) Evaporation will take place much more rapidly from a soil that is bare, or partially so, than from a soil that is well clothed with grass. I filled two zinc boxes with sandy loam and with strong clay, and adjusted them on a balance. Into each the same quantity of water was put. The thermometer in the sandy loam was lowest, and in less than a week this box rose above the other with clay, in consequence, I suppose, of more water having been evaporated from it.

Mitchell, A. (*B.* 1866, 10.)

(*Page* 303.) Little ragged clouds, something resembling uncut horsetails, are called 'fillie-tails,' and forebode windy weather when they seem to come from the south—

When frae the south whusk fillie-tails,
Then high ships wear low sails.
(Galloway.)

Noah's Ark.—In the winter season—for the ark is not common in any other—when the sky is clear and the weather frosty, curious light grey clouds, in the shape of ribs, will oft arise from a point in the horizon, and stretch over the sky to its opposite point on the other side. These cloudy ribs narrow in bulk towards the horizon, and are at the widest right over our heads, or in the zenith. In this form (*Page* 304) it will appear for a day together or even longer. What is singular, too, is we have no half-arks ; the one half never sinks below the horizon, and leaves the other half alone. We have it as if it were calculated to appear in our latitude and longitude ; for it begins to form, comes to perfection, and vanishes away all in our canopy. When seen in frosty weather—and it generally is—weather-wise folk prognosticate a thaw, instantly attended 'wi' an awful spate.' The ark is a great thaw sign. The ark is not always regarded as a forerunner of bad weather. When it runs north and south, the aftercome is not so much dreaded as when it is stretched between any of the other points. (Galloway.)

(*Page* 305.) Clear to the south will drown a ploughman. (Berwickshire.)

Grumphie smells the weather,
And grumphie sees the wun',
He kens when cluds will gather
And smoors the blinking sun.
(Galloway.)
[? Should it not be smoor,]

Semenof. *Journ. Roy. Geog. Soc.*, vol. xxxv. (1866) (*rsp*).

(*Page* 226.) Dry atmosphere has the effect of raising the snow-line. Hence the elevation of this line above the normal altitude for the latitude indicates a dry air. (*Page* 227) Rhododendrons mark a moist atmosphere.

Temple, R. *Journ. Roy. Geog. Soc.*, vol. xxxv. (1866) (*rsp*).

(*Page* 71.) On the plateau of Chutteesgurh the soil is so moist that the sugar cane can be grown without irrigation. It is itself destitute of wood, but is surrounded by forests.

Wilson, J. Fox. *Journ. Roy. Geog. Soc.*, vol. xxxv. (1866) (*rsp*).

(*Page* 113.) During the year 1862 a severe drought prevailed throughout Cape (*Page* 114) Colony and South Africa. Livingstone refers to the dry season in the Bakwain country, and mentions, as indicative of the dryness of the air, that needles lying out of doors for months did not rust ; that a mixture of sulphuric acid and water parted with its water to the air ; that the leaves of indigenous plants were drooping, soft and shrivelled ; and that the leaves of mimosæ were closed by day as well as by night.

1867.

Blackmore, R. D. *Symons's Meteorol. Mag.*, vol. ii. (1867) (*rsp*).

(*Page* 81.) Teddington. On the evening of July 24th there was noticed a very peculiar appearance in the south-east after sunset. The sky was chiefly overcast with a free display of red streamers all over the east and south ; but in the south-east was a beautiful fan of blue divergent radii, rising 30° above the horizon, and breaking across the redness like a windmill with blue sails. On the night of the 25th there was a tremendous downpour of rain.

Brumham, G. D. *Symons's Meteorol. Mag.*, vol. ii. (1867) (*rsp*).

(*Page* 40.) [He conjectures that there may be a 29-year period in meteorology,

and he extracts from Whistlecraft's works all the cases that appear to indicate this. Those only are given here which refer to dry weather.]

1746. An exceedingly hot and dry summer.
1747. Dry season.
1759. A hot summer and dry.
1760. Very hot and dry summer.
1762. A very hot and dry summer, and a very dry year.
1765. A very dry summer, and often very hot.
1771. A very dry summer and year.

1775. A hot and dry summer.
1776. Chiefly dry and fine from May.
(*Page* 41.)
1781. A hot, dry summer.
1793. Intensely hot and dry part of summer.
1802. Hot and dry two months of the summer (August and September).
1818. A remarkably dry and hot summer.
1819. A hot and dry summer.
1822. Great heat and drought part of summer. Very fine till October.
1834. Sharp drought in spring and greater part of summer, and generally very hot.
1835. A very hot and dry summer, and very great drought in July and August.

1775. Summer dry and hot.
1776. Chiefly dry and fine from June.
1788. A hot summer and dry year.
1789. Rather wet summer.
1791. A very hot and dry summer, and a very dry year.
1794. Rather a dry summer and very hot from June 12th to July 18th.
1800. Excessive drought from June 22nd to August 19th.
1804. Extremely hot and dry in September.
1805. Very hot.

1810. A dry year to October.
1822. Great heat and drought part of summer.
1831. Hot and dry two months of the summer (July and Angust).
1847. A remarkably dry and hot summer.
1848. A wet summer.
1851. Great heat and drought part of summer. Very fine till end of October.
1863. Sharp drought in spring and summer, and generally very hot.
1864. A very hot and dry summer, and very great in July and August.

1867.

Buchan, A. (*B.* 1867, 3.)

(*Page* 3.) The hygrometer is an instrument of great value in meteorology, (*Page* 4) as indicating the quantity of vapour in the air, and inferentially the changes of weather depending thereon. De Saussure may be considered the founder of this department of meteorology by his researches. Pictet made valuable observations on dew. Patrick Wilson missed the point of the argument in continuing (*Page* 5) to entertain the notion that the cold accompanying dew was after, instead of before, its deposition. Dr. Wells collected the observations into a coherent whole, and accounted for them by his theory of dew, which all succeeding inquiry has confirmed. His 'Theory of Dew,' published in 1814, must always be regarded as one of the greatest contributions made to meteorology. Dr. Wells made the discovery that during those nights when dew is deposited, the temperature of bodies on the earth's surface is colder than that of the surrounding air. In 1823, Daniell discussed in his 'Meteorological Essays' the hygrometry of the atmosphere and evaporation. Hygrometry is indebted to him more than to any other philosopher. The law of the diffusion of vapour through the air, its influence on the barometric pressure, and its relation to the other constituents of the atmosphere, are among the least satisfactorily determined questions in meteorology. Since this element is so important as an indicator of storm and other changes of the weather, it is to be hoped it will soon be more thoroughly investigated. A most important addition to our knowledge of the atmosphere was made in 1862 by Prof. Tyndall, in his (*Page* 6) experiments on radiant heat, especially as regards the gases, by which it is shown that the vapour of water exerts extraordinary energy as a radiant and absorbent of heat. It is to be expected that the relations of atmospheric vapour will soon be turned to account in explaining many questions of meteorological (*Page* 24) inquiry. The barometer is influenced to a large extent by the elastic force of the vapour of water, invisibly suspended in the atmosphere, in the same way as it is influenced by the dry air. But the vapour of water also exerts a

pressure on the barometer in another way. Vapour tends to diffuse itself equally through the air; but as the particles of air offer an obstruction to the watery particles, about 9 or 10 a.m., when evaporation is most rapid, the vapour is accumulated or pent up in the lowest stratum of the atmosphere, and being impeded in its ascent, its elastic force is increased by the reaction, and the barometer consequently rises. When the air falls below the temperature of the dew point, part of the vapour is deposited in dew, and since some time must elapse before the vapour of the upper strata can diffuse itself downwards to supply the deficiency, the barometer falls most rapidly at 10 p.m., when the deposition of dew is greatest. As regards vapour in the atmosphere, the barometer is subject to two maxima and minima of pressure—the maxima occurring at 10 a.m., when, owing to rapid evaporation, the accumulation of vapour near the surface is greatest, and about sunset, or just before dew begins to be deposited, when the relative amount of vapour is greatest; and the minima in the evening, when the deposition of dew is greatest, and before sunrise, when evaporation and the quantity of vapour in the air is least. Thus the maximum in the forenoon is brought about by the rapid evaporation arising from the dryness of the air, and the increasing temperature. But as the vapour becomes more equally diffused, and the air more saturated, evaporation proceeds more languidly; the air becomes more expanded by the heat, and flows away to meet the diurnal wave of cold advancing from the eastward. Thus the pressure falls to the afternoon minimum about 4 p.m. From this time the temperature declines, the air approaches more nearly the point of saturation, and the pressure being further increased by accession of air from the warm wave now considerably to the westward, the evening maximum is attained. As the deposition of dew proceeds, the air becomes drier, the elastic pressure of the vapour is greatly diminished, and the pressure falls to a second minimum about (*Page* 25) 4 a.m. The amount of these daily variations diminishes from the equator towards either pole, for the obvious reason that they depend, directly or indirectly, on the heating power of the sun's rays. Thus, while at the equator the daily fluctuation is 0·125 in., in Great Britain it is only a sixth part of that amount. It is very small in the high latitudes of St. Petersburg and Bossekop; and in still higher latitudes at that period of the year when there is no alternation of day and night, the diurnal variation probably does not occur. In the dry climate of Barnaul, in Siberia, there is no evening maximum; the lowest minimum occurs as early as midnight, and the only maximum at 9 a.m. So far as the dry air of the atmosphere is concerned, the atmospheric pressure will be least in the summer and greatest in the winter of each hemisphere [warm and cold hemispheres north and south]. But the production of aqueous vapour by evaporation being most active in summer, the barometer will be much increased from this cause. As the aqueous vapour is transferred to the colder hemisphere it will be there condensed into rain, and being thereby withdrawn from the atmosphere, the barometer pressure will be diminished, but the dry air which the vapour brought with it from the warm (*Page* 26) hemisphere will remain, thus tending to increase the pressure. The barometer is high at Calcutta in January, owing to the dry, cold, dense air of Central Asia being conveyed southward over India. At places where the amount of vapour in the air varies little from month to month, but the variations of temperature are great, the differences between the summer and winter pressures are very striking. Thus, at Barnaul and Irkutsk, both in Siberia, the pressures in July are respectively 29·243 and 28·267, and in January 29·897 and 28·865, the differences being upwards of six-tenths of an inch. The great heat of summer in Siberia causes the air to expand and flow away in all directions, and the diminished pressure is not compensated for by any material accession being made to the aqueous vapour of the atmosphere; and, on the other hand, the great cold and

little rain in that region during winter causes high pressures to prevail during that season. The same peculiarity is seen, though in a modified degree, at St. Petersburg, Moscow, and Vienna. At Reykjavik, in Iceland, the pressure in June is 29·717, and in December 29·273; at Sandwich [=Sandwick], Orkney, 29·775 and 29·586; and at Sitcha [=Sitka], in Russian America, 29·975 and 29·664. In all these places the distribution is just the reverse of what obtains in Siberia, being least in winter and greatest in summer. The high summer pressures are due to the cool summer temperature as compared with surrounding countries; thus causing an inflow from these regions; and to the large amount of vapour in the atmosphere, thus still further raising the barometric column. On the other hand, the low winter pressures are due to the high winter temperatures, causing an outflow toward adjoining countries, and the large winter rainfall, which sets free great quantities of latent heat. The variations in mean pressure are very slight, and not marked by any decided regularity in their march through the seasons, at Dublin, Glasgow, London, Paris, and Rome. As compared with Barnaul and Reykjavik, their temperature is at no season very different from that of surrounding countries, and the rainfall and vapour are at no time much in excess or defect, but are more equally (*Page* 48) distributed over the different months of the year. The temperature of plants exposed to the sun's rays is not so high as that of the soil under the same circumstances, partly because a portion of the solar heat is lost in the process of evaporation from the pores of the plants. Evaporation goes on slowly from damp ground under the trees, being screened by them from the sun's heat. But since the air among the trees is little agitated or put into circulation by the wind, the vapour which arises from the soil is mostly left to accumulate above it. Hence, though exact observations are wanting to settle the question, it is probable that forests diminish the evaporation and increase the humidity. It is not deposited in cloudy weather because the clouds obstruct the escape of heat by radiation into space; nor in windy weather, because wind constantly renews the air in contact with the ground, and thus prevents the temperature from falling sufficiently low. No dew is deposited on the surface of deep water, because its temperature scarcely ever falls below the dew point. When the temperature is below the freezing point the dew (*Page* 68) freezes as it is deposited, and hoar frost is produced. The specific gravity of the ocean is high where the evaporation is great, as in the region of the trade (*Page* 74) winds. The equatorial current [wind] losing heat as it proceeds on its (*Page* 75) course is thereby brought nearer the point of saturation, and consequently becomes a moister wind; while the polar current, gaining heat in its progress towards the equator, becomes a drier wind. The chief effect mountain ranges have on temperature is to drain the winds which cross them of their moisture, and thus to cause colder winters and hotter summers in places to the leeward, as compared with places to the windward, by more fully exposing them to both solar and terrestrial radiations. The western parts of the continents in the north temperate zone are protected from extreme cold by their moist atmosphere and clouded skies. But in the interior of continents it is otherwise; for the winds getting colder and drier as they advance the soil is exposed to the full effects of radiation during the long (*Page* 76) winter nights. Since the air over continents is drier than on sea shores, (*Page* 80) the heating power of the sun's rays is very great during the long days of summer. The quantity of aqueous vapour in the atmosphere is by the processes of evaporation and condensation varying every instant. Vapour diffuses itself through dry air, the presence of dry air having only the effect of retarding the rate of its diffusion. If the vapour of water remained permanently in the atmosphere—that is, was not liable to be withdrawn from it by being condensed into rain—the mixture would be as complete and uniform as that of the oxygen with nitrogen. But the equilibrium of the vapour atmosphere is being constantly disturbed by

every instance of condensation, by the ceaseless process of evaporation, and by every change of temperature. From these condensations and from the circumstance that the dry air greatly obstructs the free diffusion of the vapour, it follows that the law of the independent pressure of the vapour and of the dry air of the atmosphere does not absolutely hold good, but that from the constant effort of the vapour to attain to a state of equilibrium there is a continual tendency to approach to it. And since the independent and equal diffusion of the dry air and the vapour is owing to disturbing causes never reached, it follows that the observations of the hygrometer only indicate local humidity, and should only be regarded as approximations to a correct indication of the quantity of vapour in the atmosphere over the place of observation. It should, however, be added that, though in exceptional cases the amount of vapour indicated may be wide from the mark, yet in long averages a very close approximation will be obtained. When water evaporates into air the maximum density of the vapour is not acquired till some time has elapsed. (*Page* 83) And since every addition to the vapour increases the pressure, the rate of evaporation is continually diminishing. The amount of evaporation is measured by an evaporimeter, which is usually an evaporating dish about 5 in. in diameter, with an overflow pipe and wirework cover. The best is Mitchell's, which is made on the principle of the fountain inkstand. The advantages are that dew and rain are at once carried away, and that minute quantities can be read off. James Procter Barry's is a modification. The surface is 10 in. square. The small quantity evaporated daily is measured by a scale of brass divided into 10 equal parts placed diagonally in the evaporimeter, so that during the evaporation of one inch of water the line of contact of the surface of the water with the diagonal scale will traverse the whole length of the scale. The $\frac{1}{100}$ of an inch can be easily read. The atmo- (*Page* 84) meter is of some practical use. It is a long glass tube attached to a hollow ball of porous earthenware. The tube is filled previous to observing. There is no class of observations which show such diversity of results as those made by observers of evaporation owing to different methods being employed. The object sought to be obtained is the drying power of the atmosphere. The ocean loses more heat from evaporation than land, because the quantity evaporated from its surface is much greater. Theory should lead us to suppose that the temperature of drained land would be higher than that of undrained, because being drier less heat (*Page* 85) is lost by evaporation. In 1862 the Marquess of Tweeddale offered prizes for sets of observations on this point. Two sets of observations for a year were made, one at Otter House, in Argyle, on arable land, under a rye-grass crop, the soil being light and sandy, and the slope being 1 in 40; the other set at North Esk reservoir, Pentland Hills, on hill pasture, the soil being clay mixed with decayed moss. The following results were drawn. 1. The mean annual temperature of the arable land was raised 8° by drainage, and (2) that of the pasture land, 4°. 3. During sudden falls of temperature and during protracted cold weather, the cold passed more quickly and completely through undrained land than through drained land. 4. When the temperature of the air was higher than that of the soil, drained land received more benefit from the higher temperature than the undrained land, less of its heat being lost by evaporation. 5. Since when rain or sleet fell the superfluous moisture soon flowed away from the drained land, drainage tended to maintain in the soil a comparatively equable temperature; whereas the undrained land was liable to considerable fluctuation, for when soaked with warm rain water its temperature was temporarily raised, and when soaked with melted snow it was temporarily lowered. On one occasion sleet lowered the drained land 2° and the undrained land 4°. 6. The temperature of drained land was in summer occasionally raised above undrained land 3°, and often 2°, and still more frequently 1·5°. Since these different temperatures are chiefly

caused by the different amounts of water evaporated from the land, it is evident that different results will be obtained from different soils with different crops and with different slopes and exposures. In 1847 Prof. James Elliott made a number of experiments which shed some light on this extensive subject. He found that peat moss can absorb more than twice its own weight of water, dry clay nearly its own weight, dry earth or garden mould more than half its own weight, and dry sand little more than a third of its own weight. With equal times of drying under the same circumstances peat moss lost two-thirds of all the water it contained; clay and earth each more than three-quarters, and sand more than nine-tenths. Evapo- (*Page* 86) ration was greater from the surface of loose earth than from the surface of water, till the earth became so far dry as to be of a light colour. Evaporation from saturated moss was excessive during the first day, being far more than from the surface of water, but on the second day the water began to evaporate most, and on the third day very much more than the moss, although the moss was still wet 10 in. below the surface. From these experiments [those by Dr. Milne Home under 1866 being included] a few practical conclusions may be drawn. In all cases the amount evaporated from wet substances and the consequent decrease of temperature is proportional to the number of evaporating points, or to the whole extent of the evaporating surface in contact with the air. This explains why evaporation is greater from wet moss and grass than from wet soils, and greater from wet soils than from a surface of water. But as evaporation proceeds and the substances begin to dry, the rate of evaporation is modified by the facility with which the water is drawn by capillary attraction from the interior of the substances to their evaporating surfaces. Thus dry sand parts with its moisture sooner than clay, and clay sooner than peat moss. At all temperatures, even the lowest, moisture exists in the atmosphere in an invisible state, so that the air is never (*Page* 87) absolutely dry. Prof. J. D. Everett found that the exact correspondence of the dry and wet bulb thermometers which happens when the air is quite saturated was as rare as eclipses of the sun or moon. The air a few feet above the ground is seldom perfectly saturated. The capacity of the air for moisture increases at a more rapid rate than the temperature. Thus air can contain at 32° the $\frac{1}{160}$ part of its own weight; at 59° the $\frac{1}{80}$; and at 86° the $\frac{1}{40}$; the law being that for every increase of 27° the capacity is doubled. Some hygrometers are formed of substances which readily take up and part with moisture, as Saussure's hair hygrometer. Adie's is made with two pieces of wood glued together. It is of little (*Page* 88) or no scientific value. It is this property of substances to be changed in bulk in attracting moisture or in parting with it, which explains a large number of popular prognostics of the weather, especially such as refer to the feelings and conduct of animals, the opening and closing of flowers, and the lengthening and shortening of strings, cordage, and other materials. Hygrometers constructed on the principle of absorption are faulty, not only because they are irregular in their action, but also because, in the course of time, they are subject to great change. The most accurate hygrometers are those constructed on the principle of condensation or of evaporation. Daniell's and Regnault's are constructed on the principle (*Page* 89) of ascertaining the dew-point temperature. Daniell's is the simplest, but Regnault's requires less time in making the observations. The dry and wet bulb thermometer is the most convenient. Some precaution is required in taking the observations when the temperature of the air is below 32°. If the wet bulb reads higher than the dry the observation should not be recorded. If the muslin is (*Page* 90) dry it should be wetted, and time allowed for the water to freeze before reading the temperature. When the temperature rises above 32° the ice should be removed. Both the thermometers should be exactly the same. All foreign matter should be washed out of the cotton or muslin. The water

used should be pure, either rain or distilled. The muslin should not be touched with the fingers, which cause it to become slightly greasy. The glass vessel should be as far as possible from the dry bulb. The best hours for observation are 9 A.M. and 9 P.M. An additional observation is recommended at 3 P.M. By means of observations of the dry and wet bulb thermometers we may determine or approximate to by means of tables: (1) The dew-point; (2) the elastic force of vapour; (3) the quantity of vapour in a cubic foot of air; (4) the additional vapour required to saturate a cubic foot of air; (5) the relative humidity; and (6) the weight of a cubic foot of air at the pressure prevailing when the observation is made. (*Page* 92). The elastic force of vapour may be regarded as representing the absolute quantity of vapour suspended in the atmosphere. It may also be termed the absolute humidity. It is greatest within the tropics. It is greater at midday than in the morning. It also diminishes with height, but the average rate at which it diminishes is not known. The balloon ascents of Mr. Glaisher and some other aeronauts have thrown some light on the question. But the number of ascents are by far too few to warrant the drawing of general conclusions as to the mean rate of the decrease. The chief point established is that in particular instances the decrease is generally far from uniform, as different strata are super-imposed on each other, differing widely as regards dryness and dampness. Relative humidity is distinct from this, and by humidity of air meteorologists mean the degree of its approach to saturation. Air of a humidity of 73° would feel very dry to an inhabitant of Great Britain, 73° being about the lowest mean humidity that occurs in Scotland during May, the driest month. This low humidity is, however, greatly exceeded when the east winds of spring happen to acquire their greatest virulence and dryness. Thus during May 1866, at Corrimony in Inverness-shire, the dry bulb at 9 A.M. of the 21st was 65°, and the wet 47°, thus giving a humidity of 29°, perhaps as low a humidity as has hitherto been observed in the British Isles; and of course later in the day this extraordinary dryness must have been still further increased. In the ocean at a distance from land the humidity is always great, and during the (*Page* 94) night generally approaches 100°. In the interior of continents it is less, especially in sandy deserts, which allow the rain water speedily to sink, thus drying the surface; and in rocky countries which are never wetted more than on the surface. Thus at Djeddah, in Arabia, on 12th March, 1864, the humidity was as low as 11°. The humidity is greatest during the night, when the temperature is at its minimum; it is also great in the morning, when the sun's rays have evaporated the dew and the vapour has not yet had time to find its way into the air. And it is least during the greatest heat of the day, and for some time thereafter or before the temperature has yet begun perceptibly to fall. Now between the vapour present in the air and the temperature of the air there is a vital and all-important connection (*Page* 99) which recent experiments and researches have done much to elucidate. When rivers are considerably warmer than the air they give rise to fogs, because the more rapid evaporation from the warm water pours more vapour into the atmosphere than it can hold suspended in an invisible state, and the surplus vapour is condensed into mist by the colder air through which it rises. Thus deep lakes and rivers flowing out of them are in winter generally much warmer than the air, and hence, when the air is cold and its humidity great, they are covered with fogs. When Sir Humphry Davy descended the Danube in 1818, he observed that mist was always formed during the night, when the temperature of the air on shore was from 3° to 6° lower than that of the stream; but when the sun rose, and the temperature was brought to an equality, the mist rapidly disappeared. The densest fogs occur during the cold months in large towns built on rivers, the causes which produce fogs being then at the maximum. The denseness of the London fogs is notorious. This peculiar denseness is caused by the warmth of the river bed, and

it is increased by the sources of artificial heat which London affords ; and from the circumstance that the temperature is falling everywhere, and the humidity being then great, the vapour of the atmosphere is quickly and copiously condensed by the gently flowing cold easterly winds which generally prevail in November. In all these cases fogs are very locally distributed, being confined to the basin of the river or lake where they are formed, and do not extend far up into the atmosphere. There are, however, other fogs that spread over large districts which are originated under different meteorological conditions. Fogs often accompany the breaking of frosts in winter. For when the humid south-west wind has gained the ascendency, and is now advancing over the earth's surface as a light air, it is chilled by contact with the cold ground, and its abundant vapour thereby condensed into a wide-spread mist. Hills and mountains are frequently covered with mists. Since the temperature of the air falls with the height, it follows that as the warm air is driven up the slopes of the mountains by the wind, it becomes gradually colder, and its capacity for moisture is thereby diminished until condensation takes place, and the (*Page* 100) mountain is swathed with mist. Owing to the peculiarity of their temperature, forests have a marked effect on the mists of mountainous regions. Mists often appear sooner on the parts of hills covered with trees than elsewhere. This happens especially when the mist begins to form after midday, because then the temperature of the trees is lower than that of grassy slopes. Mists also linger longer over forests, probably on account of their increased cold arising from the large extent of evaporating surface presented by their leaves when drenched with mists. During his residence at the Cape of Good Hope, Sir John Herschel observed a remarkable instance of the influence of trees in condensing the vapour of the atmosphere. On the side of Table Mountain from which the wind blew, the clouds descended very low, frequently without any rain falling, while on the opposite side they covered the mountain in dense masses of vapour. When walking beneath tall fir-trees, at the time these clouds were closely overhead, he was subjected to a heavy shower of rain ; but on going out from beneath the trees the rain ceased. The explanation he gave of the phenomenon was that the clouds were condensed into rain on the cool tops of the trees. And doubtless the innumerable fine leaves of the fir-trees adding largely to the surface of evaporation, increased the cold, which condensed the vapour into a more copious shower. I am informed by the Rev. J. Farquharson, Selkirk, that when the atmosphere is very moist, and the S.W. wind is blowing strongly, a mist or cloud is sometimes seen to settle over Bowhill, which is situated at the junction of the Yarrow and Ettrick ; and that the cloud thus formed is subject to great and rapid changes, both as regards its outline and its size. This is a highly instructive observation considered with reference to the causes which produce the phenomenon. Both valleys lie nearly in the direction of the S.W. wind, but the vale of Ettrick is the more highly wooded of the two ; hence the temperature of the two valleys will, from what has been stated above, be generally different the one from the other. Now when a steady humid S.W. wind is blowing, each will acquire the temperature of the valley down which it has flowed, and be at the same time near the point of saturation ; and at Bowhill, where the two aerial currents meet and mix together, cloud will be formed, in accordance with the well-known law by which two volumes of air, each saturated but of different temperatures, can, when mixed, no longer hold all the vapour in suspension, so that consequently part is condensed into cloud or vapour. Extensive fogs also prevail (*Page* 101) where great differences occur in the temperature of contiguous regions. Thus promontories running out into the sea are frequently enveloped in mist ; for since land is generally warmer than the sea in summer and colder in winter, the difference of temperature is generally sufficient to cause mists with the veerings of the wind landward or seaward. The same cause explains the mists and fogs which

frequently prevail on the coast. These mists generally occur in the morning and evening, seldom advance far inland, and usually accompany fine weather. The British Isles being bounded by the warm waters of the Atlantic on the one side, and separated from the Continent on the other only by narrow belts of sea, are subject to fogs during winter. For the same reason dense thick fogs are prevalent in Norway, Newfoundland, along the coast of Peru and South Africa, and in the Polar regions. The Gulf Stream is notorious for dense and long-continued fogs, particularly at its northern limit, where it meets the Polar current. The high temperature of the stream, which is often from 16° to 18° and sometimes 30° higher than that part of the sea past which it flows, fully explains the denseness and persistency of these fogs. Occasionally the summit of a hill or isolated peak is wrapped in mist or cloud, while elsewhere the atmosphere is clear, and though a breeze be blowing over the hill, still

> 'Overhead
> The light cloud smoulders on the summer crag,'

apparently motionless and unchanged. This phenomenon is instructive and easily explained. The temperature at the top is below the dew-point of the atmospheric (*Page* 102) current. Hence when the air rises to this region its moisture is condensed into cloud, which is borne forward over the top of the hill and down the other side, acquiring heat as it descends till it is again dissolved and disappears. Meanwhile its place is constantly supplied by fresh condensations which take place as the current, rising to the height of the cloud, falls below the temperature of saturation. Thus, though the cloud on the top of the hill appears to remain motionless and unchanged, the watery particles of which it is composed are continually undergoing renewal. There is another sort of fog of occasional occurrence differing from any of the foregoing, which, from its relation to storms, is of considerable importance in meteorology. It would appear to arise from the juxtaposition of the Polar and equatorial currents. When these currents flow side by side, fog frequently fills up the comparatively calm space intervening between them. It results from the mixing together of the two currents, the cold of the Polar current condensing the vapour of the S.W. wind. It sometimes stretches several hundred miles in the form of a long narrow strip. At other times, and more usually, it is a precursor of storms, which succeed fine dry weather, during which the wind has been chiefly from the N.E. The S.W. wind is seen to prevail in the upper regions of the atmosphere, by the direction in which the thin cirrus cloud is blown, some time before it is felt on the surface of the earth. During this interval the humid equatorial current overlaps the Polar current, and the fog which prevails is due to the mixing of the two currents. Hence in discussing storms, fogs constitute one of the most important elements which require consideration, and they supply valuable help towards the foretelling of storms. Clouds, mists, and fogs arise from the same causes. During the warmest part of the day, when evaporation is greatest, moist air currents are constantly ascending from the earth. As they rise in succession, the moist air is pushed high up into the atmosphere, and losing heat by expansion, a point is at length reached when it can no longer retain in solution the moisture with which it is charged; hence condensation takes place, and a cloud is formed, which increases in bulk as long as the air continues to ascend. But as the day (*Page* 103) declines, and evaporation is checked, the ascending current ceases, and the temperature falling from the earth's surface upwards, the lower stratum of the air contracts, and consequently the whole mass of air begins to descend, and the clouds are then dissolved by the warmth they acquire in falling to lower levels. The whole of the process is frequently seen on a warm summer's day. In the morning the sky is cloudless, or nearly so; as the heat becomes reater, clouds

begin to form, and increase in number and size, often presenting scenes of unparalleled beauty, as lighted up by the sun into dazzling brilliance, they sail slowly and smoothly across the blue sky; but as the heat diminishes, they contract their dimensions and gather round the setting sun, lit up with the fiery splendours of his beams. In a short time they disappear, and the stars come out, shining in a cloudless sky. When a dry and heavy wind begins to set in, or takes the place of a moist and light wind, it generally does so by edging itself below the moist wind, and forcing it wedgeways into the upper regions of the atmosphere, where condensation rapidly follows, and dense black clouds, often heavily charged with rain, are formed. This is a frequent cause of cloud and rain in Great Britain, when the cold heavy east wind or Polar current thrusts high up into the air the rain-bringing S.W. wind, thus causing it to darken the sky and bring down its surplus moisture (*Page* 104) in torrents of rain. Espy has reasoned that every cloud is either a forming cloud or a dissolving cloud. While it is connected with air-ascending currents it increases in size, is dense at the top, and well defined in its outlines; but when the ascending current ceases, the cloud diminishes in size and density. When a cloud overspreads the sky its lower surface is, for the most part, horizontal, or more generally, it seems as if it was an impression taken from the contour of the earth's surface beneath it. This arises from the high temperature of the air below the cloud, which is sufficient to dissolve the particles as they descend below its level. On ascending through this lower stratum of cloud the temperature is found frequently to rise, and the air to be quite clear of clouds for a considerable thickness. Higher up a second stratum of cloud succeeds, and again another clear space, and so on, cloud and clear sky following each other several times in succession. These phenomena arise from the different currents which are encountered superimposed over each other, and differing in temperature and humidity. Kaemtz has deduced (*Page* 105) the heights between which clouds range as from 1,300 to 21,320 feet. The extreme height is, however, much too small, as has been proved by balloon ascents. Thus Gay Lussac in September 1804, when at the height of 23,000 feet, saw clouds floating apparently at a great height above him. It is probable that the cirrus cloud is often ten miles above the earth. Since clouds are subject to certain distinct modifications from the same causes which produce the other atmospheric phenomena, the face of the sky may be regarded as indicating the operation of these causes. The ancient meteorologist was content with discerning the face of the sky, in order to predict the coming weather. It is to this that the weather-wise sailor and the farmer still look in foretelling the weather. The classification of clouds universally adopted is that proposed by Luke Howard in 1803. The cirrus is the cloud first seen after serene weather. The duration of the cirrus varies from a few (*Page* 106) minutes to many hours. It remains for a short time when formed in the lower parts of the atmosphere, and longest when it appears alone in the sky, and at a great height. The cirrus, though apparently motionless, is closely connected with the movements of great atmospheric currents. It is this intimate connection which has long caused it to be considered as a most valuable prognostic of stormy weather, and as such it deserves more attention than has hitherto been given to it. Small groups of regularly-formed and arranged cirrus scattered over the sky often accompany fair weather and light breezes; these do not indicate the approach of a storm for some time at least. Horizontal sheets of this cloud, which fall quickly, and pass into the cirro-stratus cloud, indicate in an unmistakable manner continued wet weather, when streaks of cirrus run quite across the sky in the direction in which a light wind happens to blow, the wind will probably soon blow hard, but it will continue in the same direction; in other words, the variable winds and fitful gusts which accompany storms are not likely to be experienced when the fine threads of the cirrus appear blown, or brushed backwards at one end, as if by a

wind prevailing in those upper regions, the wind on the surface will ultimately veer round to that point. If the direction indicated be from south-west, whence the storms of Europe come, wind and rain may be expected ; and it matters not how fair and settled like the weather appear at the time, a storm more or less severe is advancing, and may be looked for within thirty or forty-eight hours. When the storm seems past, and the sky has cleared, should a few fine cirrus clouds be seen slightly blown back at their eastern extremities, the storm has in all likelihood really passed, and fair weather may be expected with some confidence, since the dry Polar current has already begun to prevail overhead. But if, instead of this, innumerable groups and streaks of cirrus cover the sky, crossing each other in all directions, and presenting the appearance of a skein of yarn inextricably tangled together, we may be sure a second storm will shortly follow the one already past. The cumulus clouds are formed in the lower regions of the atmosphere, and are carried along in the current next the earth. The cumulus has been well called the cloud of day, being caused by (*Page* 107) the ascending currents of warm air which rise from the heated ground. When the cumulus clouds are of moderate height and size, of a well-defined curved outline, and appear only during the heat of the day, they indicate a continuance of fair weather. But when they increase with great rapidity, sink down into the lower parts of the atmosphere, and do not disappear towards evening, rain may be expected. If loose, fleecy patches of cloud begin to appear, thrown out from their surfaces, the rain is near at hand. The stratus is the lowest sort of cloud, its lower surface commonly resting on the earth. The stratus may be called the cloud of night, since it generally forms about sunset, grows denser during the night, and disappears about sunrise. It is caused by the vapours which rise during the day, but towards evening fall to the earth with the falling temperature ; and since during night the cooling of the air begins on the ground, and thence proceeds upwards, the stratus first appears like a thin mist floating near the surface of the earth ; it thence increases from below upwards as successive layers of the air are reduced below the point of saturation. It includes all those mists which in the calm evening of a warm summer day form in the bottom of valleys and over low-lying grounds, and then spread upwards over the surrounding country like an inundation. When the sun has risen, and begun to shine on the upper surface of the stratus cloud, it begins to be agitated, and heaved up in different places into the rounded forms of the cumulus, while at the same time the whole of the lower surface begins to rise from the ground. As the heat increases, it continues to ascend, and becomes broken up into detached masses, and soon disappears altogether. These appearances indicate a continuance of the finest and serenest (*Page* 108) weather. While the cirrus changes into the cirro-cumulus, it generally descends to a lower position in the atmosphere. This beautiful cloud, commonly known as a ‘ mackerel ’ sky, occurs frequently in summer, and is attendant on dry and warm weather. It is also sometimes seen between showers. But in this case the cirro-cumulus will be found wanting in the settled order which it wears in fine weather. The cirro-stratus is markedly a precursor of storms ; and from its greater or less abundance and permanence, it gives some indication of the time when the storm may be expected. It may generally be seen between storms, occasionally with the cirro-cumulus, and from what then takes place, important information may be learned regarding the continuance or non-continuance of the stormy weather then prevailing. For if the cirro-cumulus give way, or pass into the cirro-stratus, more wind and rain may be confidently expected ; but if the cirro-cumulus prevail, (*Page* 109) the storm is past, and fair weather may be looked for. The cumulo-stratus appears indistinctly in the intervals of showers. The distinct cumulo-stratus is formed when the cumulus becomes surrounded with small fleecy clouds just before rain begins to fall, and also on the approach of thunderstorms. The

rain-cloud often has its origin in the cumulo-stratus, which increases till it overspreads the sky and becomes black, or bluish-black, in colour; but this colour soon changing to grey, the nimbus is formed, and rain soon begins to fall. At a considerable height a sheet of cirro-stratus cloud is spread out, under which cumulus clouds drift from the windward; these rapidly increasing, unite at all points, forming one continuous grey mass, from which the rain falls. It is evident from this that the whole mass of air under the upper sheet of cloud into which the clouds drift must be completely saturated. The breaking up of the loose grey mass indicates that the rain will soon cease. When a rain-cloud is seen approaching at a distance, cirri appear to shoot out from its top in all directions, and it has been observed that the more copious the rainfall, the greater is the number of the cirri thrown out from the top cloud. In observing clouds, the kind, the direction in which they are carried, and the proportion of the sky covered with them, should be noted. In estimating the amount, that portion of the sky from the horizon half-way to the zenith should not be taken into account, because the clouds being there foreshortened, the estimate would be too great. The scale generally adopted in this country is 0 to 10; 0 indicating a clear sky, 5 that it is half covered, and 10, (*Page* 111) that it is totally obscured. The rainfall is diminished, if the winds have passed over large tracts of land, particularly mountain ranges, and are, therefore, (*Page* 112) dry. The more specific conditions under which rain is precipitated, as stated by E. Renou, include :—1. Two layers of clouds at least—an upper layer, the cirrus, and a lower layer, the cumulus, or cumulo-stratus, which has its density increased, and its temperature lowered by the descent of the ice crystals of the cirrus. The geographical distribution of rain is proportioned to the humidity, etc. (*Page* 114) Rain rarely or never falls on the coast of Peru, in the great valley of the rivers Columbia and Colorado, the Sahara, and the desert of Gobi. The (*Page* 115) trade winds are in the condition of taking up moisture rather than parting with it; and the return trades which blow above them, having discharged the greater part of their moisture in the region of calms, are also dry and cloudless. In the region of calms the sun almost invariably rises in a clear sky; but about midday clouds gather, and in a short time the whole face of the sky is densely (*Page* 116) covered with black clouds, which pour down prodigious quantities of rain. Towards evening the clouds disappear, the sun sets in a clear sky, and the nights are serene and fine. The reason of this daily succession of phenomena in the belt of calms is that the air, being greatly heated by the vertical rays of the sun, ascends, drawing with it the whole mass of vapour the trade winds have brought with them, and which has been largely added to by the rapid evaporation from the belt of calms; this vapour is condensed as soon as it rises to the line of junction of the lower and upper trades. As evening sets in, the surface of the earth and the superincumbent air being cooled, the ascending currents cease, and the cooled air descends; the clouds are thus dissolved, and the sky continues clear till the returning heat of the following day brings round a recurrence of the same phenomena. The daily rains of the belt of calms are to some extent analogous in their origin and causes to the formation of the cumulus cloud of temperate climates. (*Page* 135) An important characteristic of winds is their quality, being dry or humid, etc., according to their direction and the nature of the earth's surface over which they have passed. Thus in the north hemisphere southerly winds are warm and moist, while northerly winds are cold and dry; and in the south hemisphere (*Page* 136) *vice versâ*. In certain parts of the earth circumstances occur intensifying (*Page* 146) these effects, and causing excessive drought, etc. In front of a storm the dew-point is high; in the rear, low; the high dew-point is accompanied by great humidity, and the low dew-point by a small one. When the barometer has been falling for some time, clouds begin to overspread the sky, and rain to fall at

(*Page* 147) intervals ; after the centre of the storm has passed, the rain becomes less heavy ; the clouds break up, and fine weather ultimately prevails. The physical (*Page* 158) cause of the ascending currents in the centre of storms is to be found in the moist and warm, and therefore light, air which all observation shows to prevail in the front and in the central part of storms. And since most of the rain which accompanies storms falls in those parts of the storm, the barometer will be still further reduced by the removal of the elastic aqueous vapour which is condensed into raindrops, and by the latent heat set free in the condensation of the vapour. Storms generally contract in area as they traverse a dry climate, and die out when they come to a dry polar current, as less vapour is condensed there. The usual place where the vapour brought by the trade winds is condensed is the region of calms, where heavy rains and thunderstorms occur. But since the condensation takes place simultaneously over a somewhat broad belt of the earth's surface, which for the time is stationary, it follows that the storm is neither rotatory nor progressive, the only effect of the condensation being the flow of the regular trade winds towards the belt where it takes place. When the condensation is more copious than usual, the effect will be the acceleration of the speed of the trade winds. Suppose that the atmosphere of the West Indian islands has from some cause become exceptionally warm and moist, and that at the same time a high barometer is interposed between that region and the belt of calms. In such circumstances, as the trade winds cannot flow towards the belt of calms, the usual provision for draining them of their moisture is taken away, and a rapid accumulation of aqueous vapour takes place to the north of the high barometer, ready (*Page* 167) to burst into rain and tempest. This would appear to have been the (*Page* 180) case before and after the Bahama hurricane of October 1866. The cirrus cloud sometimes appears of a texture so delicate as to elude the eyes of all but the (*Page* 181) most practised observers, and no doubt it is sometimes so thin, that the eye cannot detect it till it is revealed by electric discharges passing through it. This cloud probably originates in the equatorial current beginning to prevail in the higher regions of the atmosphere, and depositing the watery vapour necessary for the electric discharges, the faint light of which reflected by the minute crystals of the cirrus clouds forms the aurora. A large quantity of ozone in the air is associated with increasing humidity, and a small quantity with decreasing humidity. (*Page* 182) Since rainbows in the morning are always seen in the west, they indicate the advance of the raincloud from the west at the time when it is clear and bright in the east ; and since the fall of rain at this time of the day, when the temperature should be rising, is an additional evidence of increasing moisture, a morning rainbow is regarded as a prognostic of a change to wet, stormy weather. On the (*Page* 183) contrary, the conditions under which a rainbow can appear in the evening are the passing of the raincloud to the east, and a clearing up in the west at the time of day when the temperature has begun to fall, thus further indicating a change from wet to dry weather. Coronas can only be seen when the globules composing the cloud are all, or nearly all, of equal size, and the smaller the size of the globules the greater is the diameter of the corona. Hence the corona is a valuable prognostic ; for when its diameter contracts round the moon, we know that the watery particles composing it are uniting into larger ones, which by-and-by will fall in rain ; whereas, if the corona be extending, the particles are growing less, thus indicating increasing dryness, and consequently fair weather. Scoresby observed that Anthelia or glories are always seen in the Polar regions whenever (*Page* 185) sunshine and fog occur at the same time. The red and golden-coloured clouds are observed to be the accompaniment of cumulus clouds while in the act of dissolving, as they sink slowly down into the lower and warmer parts of the atmosphere ; consequently they disappear from the sky soon after sunset. Such

sunsets are universally regarded as prognostics of fine weather. Frequently small thin clouds appear high up in the eastern sky some time before sunrise, or when

'The dappled dawn doth rise,'

and when the sun has risen they disappear. They are probably caused by the sun shining on and warming the upper layers of the atmosphere before it appears above the horizon; thus small ascending currents are formed, the vapour of which as they ascend is condensed into small clouds, as the cirro-cumulus. Their rounded definite forms show them to be produced in the same way as the cumulus—viz., by ascending currents forcing their way through colder strata. They may thus be regarded as heralding the cumulus, and as sure prognostics of fine weather. If in (*Page* 186) the evening sky after stormy weather the yellow tint deepens into orange and red, the atmosphere is getting drier, and fine weather may be looked for. In the morning a red and lowering sky is a prognostic of unsettled weather.

(*Page* 196.) Table V. showing elastic force of aqueous vapour.

(*Page* 197.) Table VI. Factors for multiplying the excess of the dry bulb thermometer over that of the wet bulb to find the excess of the temperature of the air above that of the dew-point.

Buchan, A. *Journ. Scot. Meteorol. Soc.*, vol. ii. (1869), No. xiv., April 1867 (*rvp*).

(*Page* 41.) The irregular periods of temperature observable in Scotland are intimately connected with the direction of wind, and with the absolute and relative quantity of the vapour in the air. The effect of a diminished quantity of vapour in raising or depressing the mean temperature depends on the season of the year. If it occurs in summer, the mean temperature will be raised; but if in winter, it will fall. As concerns evaporation, great humidity adds to the mean temperature, and a small humidity lowers it. But as compared with solar or terrestrial radiation the effects of evaporation on the temperature are very slight. The following examples illustrate the dependence of the changes of temperature on the amount of vapour in the atmosphere. Lieut.-Col. Strachey (*Phil. Mag.*, 1866) has examined the Madras meteorological observations of several years, and compared the elastic force of the vapour with the number of degrees the temperature was reduced by terrestrial radiation from 6.40 P.M. to 5.40 A.M., and the number of degrees the solar radiation was raised from 5.40 A.M. to 1.40 P.M. In all cases examined, the sky was either quite, or all but quite, free from clouds; the only difference being in the amount of vapour. The following are selected from the results arrived at:—

TERRESTRIAL RADIATION.

Tension of vapour	·888 in.	·605 in.	·455 in.
Fall of temperature from 6·40 P.M. to 5.40 A.M.	6°	12·1°	16·5°

SOLAR RADIATION.

Tension of vapour	·824 in.	·670 in.	·394 in.
Rise of temperature from 5.40 A.M. to 1.40 P.M.	12·4°	19·3°	27·0°

Thus when the quantity of vapour in the air was very large (tension ·888 in.), the temperature only fell on an average 6° during the night; but when the quantity of vapour was small (·455) the temperature fell 16·5°. And when the quantity of vapour was large (·824) the temperature during the day rose only 12·4°; but when the amount of vapour was small, the temperature rose in the same space of time 27°. These remarks will be applied to the August cold and warm periods. The mean tension of vapour at Sandwick for August is ·360 in. For the four cold days it is only ·353 in., and on the 9th as low as ·343 in.; but for the four warm days immediately following it is ·396 in., or ·043 in. greater. The mean humidity of the

month is 85 ; of the four cold days 84 ; of the four warm days 89. Thus then, from the 8th to the 11th of August, characterised by a depression in the temperature, there was a diminished amount of vapour and less humidity. But from the 12th to (*Page* 43) the 15th, when the temperature rose, the tension increased about ·05 in. and the humidity increased from say 84 to 87. These two periods present a very striking character as regards the moisture of the air,—the warm period from the 12th to the 16th showing an amount of vapour in the atmosphere such as occurs at no other time of the year, and the cold weather of the four days preceding a deficiency of vapour greater than occurs during August until the close of the month, when, owing to the falling of temperature, the quantity of vapour is diminished. If the cold period of August was caused by the interception of heat by meteors, we should then expect with the fall of temperature an increase in the rainfall, and as the temperature would thus be brought nearer the dew-point, an increase in the humidity; and after the earth has emerged from the shadow of the meteors along with the rise of temperature, we should have a diminished rainfall and less humidity. Since the reverse of this happens, the cold of August must be explained by other causes. For this no combination of circumstances can be considered adequate which does not account for the dry, cold air prevailing during the cold period, and the warm, moist air during the warm period.

[He then investigates the condition of Western Europe as regards wind, atmosphere, pressure, and temperature relatively to Scotland, and arrives at the conclusion that the cold and warm periods of August are determined by the wind, and that the observed relations of moisture depend on the wind. The whole inquiry has a local bearing, and therefore the details are omitted here.]

Calvert, H. H. *Journ. Scot. Meteorol. Soc.*, vol. ii. (1869), No. xvi., October 1867 (*rvp*).

(*Page* 115.) At Erzeroom, June is remarkable for the regularity of the daily atmospherical change. At sunrise the sky is perfectly bright; towards 10 A.M. clouds begin to appear, which gather rapidly; and at noon, or 1 P.M., the heavens are quite overcast with heavy thunder clouds. At about 2 P.M. thunder is heard. Towards sunset the clouds are gradually dispelled, and by 9 or 10 A.M. the sky reassumes its clearness.

Laughton, J. K. (*B.* 1867, 12.)

(*Page* 445.) The dew-point in the equatorial oceanic district is perhaps seldom so much as 5° below the air temperature. Daniell has estimated the difference as generally 2° or 3°.

Lyell, Sir Charles. (*B.* 1867, 13.)

(*Page* 271.) Croll observes that when the winter occurs in aphelion during a high eccentricity of the earth's orbit the aqueous vapour would fall as snow in high latitudes, and during the summer, when the heat would be one-fifth more intense than at present, the melting of the accumulated ice and snow would give rise to (*Page* 286) constant fogs and overcast skies. When certain dry winds blow the snow wastes away like camphor by evaporation; and as it is observed that the rainfall diminishes towards the poles, it is probable that the snowfall also diminishes in that direction, so that there may be a dry air at the poles, especially if warm air from (*Page* 430) the south parts with its moisture in passing over snow-clad areas. The evaporation from some lakes is nearly equal to the quantity flowing in; and in the (*Page* 497) Caspian quite. [He says solar evaporation is a cause of oceanic currents. If so, then such currents may in some cases afford valuable evidence as to the distribution of aqueous vapour.]

Markham, C. R. *Journ. Roy. Geog. Soc.*, vol. xxxvi. (1867) (*rs*).

(*Page* 89.) The effect of vegetation is undoubtedly to retard evaporation and to check the rapidity of drainage ; and the removal of forests of course has an opposite effect. The hill districts of India afford proofs of this. The floods caused by the monsoon rains are yearly increasing in size and violence.

Mitchell, A. *Journ. Scot. Meteorol. Soc.*, vol. ii. (1869), No. xv., July 1867 (*rvp*).

(*Page* 80.) The injurious effects of the March winds of Scotland are due to their coldness and dryness. Such winds blowing over a moist surface tend to reduce the temperature of that surface to the temperature of evaporation, and thus ab- (*Page* 81) stract a large quantity of heat. Places protected from the wind will have less evaporation. The proverb says : 'Better be bitten by a snake than (*Page* 82) warmed by a March sun.' The risk may be owing to the diathermancy of the air, which is due to its dryness. It may be said that the moisture of the air is the preserver of life ; for without it every living thing would be burnt to death after sunrise or frozen to death after sunset.

Moore, J. W. *Symons's Meteorol. Mag.*, vol. ii. (1867) (*rsp*).

(*Page* 118.) The explanation of the peculiar haze which accompanies an easterly wind lies in its dryness, coldness, and consequent density with but a small capacity for vapour. The effect of its dryness—the result of its passage across land and of its coming from intensely cold regions—is excessive evaporation. But the vapour drawn up in this way is immediately condensed before it can reach to any height by the extreme coldness of the air, not in the form of a cloud, but as a haze of a most peculiar bronze hue. And this is more marked in spring, because at that season (*Page* 119) the coldness of the N.E. current is greatest and the amount of vapour carried up by evaporation reaches a maximum, from the sun, with increasing power, acting on the land drenched by the winter's snow and rain. With respect to the S.E. wind; in the first place we must carefully distinguish two distinct forms of the same. The one is nothing more than a bent polar or N.E. current, and is accompanied by all its characteristics—viz., a high barometer, great cold, the usual bronze hue, dry weather, etc. The other is a deflected S.W. or equatorial current, and is attended with a low barometer, warmth, moisture, and often heavy rain. The latter occurs in two aspects ; first, as forming one side of a cyclone, which is the most usual ; and secondly, as a comparatively steady wind, the result of an equilibrium established by opposite currents from N.E. and S.W. holding each other in check. If in the second case there is no intermingling of currents, we have towards the S.W. border of the S.E. wind a singularly transparent air and large quantities of cirrus, and towards the N.E. edge of the same the haze and high barometer characteristic of N.E. wind. The colour of the E. wind haze is the same as that of the inner edge of a solar halo, and is no doubt due to a peculiar arrangement of the vapour particles.

Russell, R. *Symons's Meteorol. Mag.*, vol. ii. (*rsp.*)

(*Page* 117.) Tyndall has exaggerated the influence which the vapour of water exerts in modifying the intensity of solar and terrestrial radiation. The radiant power of the atmospheric vapour would not form clouds, though it might form mists. In our atmosphere [English] the vapour of water had little power of transmitting its heat into space when it approaches or reaches the dew-point. If any cloud had been caused by the radiation of heat into space its upper surface would be flat, like the mists in the meadows before sunrise. These and other reasons led him to the

conclusion that the radiation of heat into space has directly a very slight influence on the production of rain.

[Sir W. Thomson's remarks on this paper will be found under his name at the bottom of this page.]

Sorby, H. C. (*B.* 1867, 16.)

(*Page* 357.) The blue colour of the sky is due to the absorption of a considerable amount of the red light by the vapour of water present as a transparent gas in a clear pure atmosphere. If, however, minute particles of water are present in the form of thin mist, the depth of the blue colour will be diminished, and hence in winter and in cold countries we have not the clear, deep blue sky of summer or of subtropical districts. The blue colour of mountains may also be explained in the same way, being due partly to the influence of the aqueous vapour, and partly to the shaded parts being illuminated by the blue sky. If the air be much charged with dry transparent vapour, the blue colour will be deeper, whereas if there be any fog or mist it will be obscured, and hence the blue colour is a sign of the air being loaded with vapour.

Stow, F. W. *Symons's Meteorol. Mag.*, vol. ii. (*rsp.*)

(*Page* 82.) At Tunbridge Wells on 27th June, four feet above ground, the humidity sank to 29·6 at 2.30 P.M. The least vapour occurred at noon; dew-point 41·1°. The temperature of the dew-point was so uniform throughout the day, that from the temperature of the air the reading of the wet bulb, almost at any time, might have been predicted when the dew-point had once been ascertained. This seems to be generally the case, at least in dry weather.

Symons, G. J. *Symons's Meteorol. Mag.*, vol. ii. (*rsp.*)

(*Page* 68.) The driest day I have hitherto recorded at Camden Town was on June 28th, 1857, when the humidity was as low as 33. On June 27th, 1867, it reached 29 at 3 P.M. four feet above the ground, the wet bulb being 58·1° and the dry 78·5°. At twenty feet above ground the lowest was at 2 P.M., being 36 ; dry bulb 77·1°, wet (*Page* 69) 59·9°. The dryness was much greater near the earth than at twenty feet above it. In both years the greatest drought was preceded by a period of easterly winds and high barometer. The range of temperature was also greatest in 1867. It was 35·1° in 1867 ; 31·3° in 1857. At Aldershot Mr. Arnold registered a humidity of 22 at 3 P.M. ; dry bulb being 82°, wet 57°.

Thomson, Sir W. *Symons's Meteorol. Mag.*, vol. ii. (*rsp.*)

[Remarks made in a discussion on Russell's paper referred to under his name.]

(*Page* 117.) He thought Russell was right that the cold of expansion had a very small effect in causing torrents of rain ; but that he had undervalued very considerably the influence of radiation in producing that minor condensation by which mists and clouds were constituted. He said minor condensation, meaning condensation from a gaseous condition into small spherical globules, was so small that the resistance they met with kept them suspended. The reason why a cloud did not fall down as rain was that every part of the cloud was composed of very minute drops of water. The larger the drops were that constituted a cloud the more rapidly would they fall ; but when very small they fell insensibly, as Professor Stokes has shown, only perhaps a few inches in an hour. When somewhat larger, they formed what we called a Scotch mist, which was something between a shower of globules coming down appreciably, and a shower of globules in which the descent was insensible. As to the influence of radiation and the influence of minor condensation as

soon as a cloud exists, whether high or low, each particle becomes a radiator. It radiates heat and becomes itself a little cooler than the surrounding air, and so becomes a reservoir of condensation. That takes place at the top of the cloud if there is clear air above it, and so with the mists of the valleys. A blade of grass (*Page* 118) could not go to a temperature lower than the dew-point of the air touching it, and so was it with particles of mist. By an arrangement which they could not but regard as an admirable and wonderful exemplification of design, there was nothing destitute of protection. The protection was sometimes insufficient, and plants were killed by frost: but some degree of protection was never wanting, and there was enough of that protection always to allow plants to live, as we saw them doing, and to survive during weather when, were it not for one of these causes, the cold would be so great as to destroy them altogether. Physically it was interesting to remark how it was that in each instance the protection was obtained. There was first the protection afforded by clouds. These prevented the surface of the earth from radiating and reaching a lower temperature than that of the clouds. The temperature of a blade of grass on a cloudy evening would therefore be very nearly the temperature of the lower surface of the clouds overhead. When there were no clouds and no wind the office of each blade of grass was to collect the air touching it, condense vapour from that air, and to take heat from part of the air around it. Thus we had a source of heat taken from the air several feet above the surface. The protection was more complete, however, when dew did not fall, for when there was no dew, the wind made up so large a portion of heat from the air that the leaves of plants were never allowed to go down even to the dew-point. Thus wind was a more complete protection than dew, and it would have been observed that plants were never injured by frosts on windy nights, and that in the morning the grass was found dry. It was sometimes remarked that flowers were frosted in hollows, but that close at hand and on hillocks they escaped damage. The air in the hollows remained unchanged, and unless there was moisture enough in the air to provide dew as long as the severe conditions of weather lasted, and to keep the dew point from going down too low, injurious effects would follow. The plants, in short got dry, drying the air around them, and if that air was not changed very much for the better then they were destroyed by frost. This, however rarely happened.

Georg Ludwig von ——. *Journ. Roy. Geog. Soc.*, vol. xxxvi. (1867) (*rs*).

(*Page* 273.) Akhtulimba (in the Belor country). Fog is of frequent occurrence in spring, and is called omimir. The mist lasts till two o'clock in the afternoon, when it suddenly disappears.

Journ. Scot. Meteorol. Soc., vol. ii. (1869), No. xvi., October 1867 (*rvp*).

(*Page* 122.) The observer at Glencairn remarks that according to the old saw the leafing of the oak before the ash indicates a dry summer. [The observer is Rev. Robert Home.]

Symons's Meteorol. Mag., vol. ii. (*rsp.*)

[No. for April 1867.]

(*Page* 35.) Steinmetz in his 'Sunshine and Showers' says: 'Much wet in May is worse than excessive drought'; hence the proverb—

'A May flood
Never did good.'

It is said that a great drought always enters during the period comprising the last eight days of February and the first twenty days of March. He also states that rain-clouds are attracted to certain localities more than others.

Symons's Meteorol. Mag., vol. ii. (*rsp.*)

[No. for July.]

(*Page* 67.) Saussure notices that before his time the hygrometers in use were formed of strings, animal fibres, and other substances which elongate or contract with damp. He points out that no one had examined the effect on any of them of variation in the pressure, density, movement, etc., of the air, nor had they examined if the varying indications of the instrument were proportional to (*Page* 68) the amount of vapour in the air. The l'Abbé Fontana rendered the method of indicating the humidity adopted by the Academicians of Cimento more portable by weighing a clean, well-polished plate of glass, reducing it to a certain temperature, and then reweighing; the difference representing the moisture condensed on it. Le Roi stood a glass in water, cooled the water till dew stood upon the glass, and then registered the temperature. Saussure rejects all these on account of inconveniences attending their use, and the liability to disturbances in the indications from the presence of grease and from other causes. Saussure tried sal-ammoniac in Le Roi's process, but states that he found that the dew did not appear at the same temperature under apparently the same circumstances. Saussure often suspended his hygrometer four feet above the (*Page* 88) ground in the middle of a large plain, waited until it took exactly the humidity of the air, and observed afterwards its momentary variations. We know that there are days when the air is calm, or no violent or decided wind agitates it; but, nevertheless, in a place perfectly open there arise from time to time slight breezes which give a momentary agitation. He invariably remarked that (*Page* 89) these slight breezes, from whatever quarter they came, caused the hygrometer to go towards dry, sometimes 1°, sometimes 2°; after which, when the air became dry, it retreated little by little to the point at which it was previously. Reflecting that these puffs arising all at once in the middle of a calm cannot surely come from far, that they are, in fact, but portions of the surface air of the same plain, compelled by a momentary rupture of equilibrium to change places; in such a plain, when the air is calm, it may be assumed that the whole was nearly of the same humidity. Why, then, should these breezes always give drier indications? Returning home he suspended the same hygrometer in the middle of a room, closed the doors and windows, sat down six feet from the hygrometer, over which he had suspended a large screen, waited quietly until he was certain that the screen and hygrometer were in the same state as the air of the room, and had taken up all possible effect from the presence of his body; then, without changing his position, he agitated the screen rapidly (like a fan); at the end of eight or ten minutes he found the hygrometer indicated $\frac{3}{4}$° drier. From subsequent rough experiments Saussure decided that these effects were due to the mingling of air from a higher level, which he assumed to be always drier. We think the point open to further investigation, the relation of aspirated and ordinary dry and wet thermometers being, we believe, only a partially investigated question. Saussure's third essay is an excellent *resumé* on evaporation. When speaking of evaporation he ridicules the idea of evaporation from a small vessel of water in a garden representing that of a large water surface like a lake or sea, and says that in order to do this fairly we should have the vessel floating even on the surface of the sea, and with the water as near as may be at the same level. The evaporator should be of such size that the water is at the same temperatures. He adopts Richmann's suggestion that the water surface should be nearly at a constant level. He notices that ice is subject to evaporation, and proves that the rate of evaporation from it is proportional to the humidity of the air. In his fourth essay he says it is the coldness of the upper regions of the air which retains and imprisons the water which nourishes the surface of the earth. Dew, which we may regard as a species of rain without clouds is

(*Page* 90) explained in the same manner; nevertheless it is sometimes accompanied by fog, and even this vapour which renders the air slightly thick when the dew falls is produced probably by some of the vesicles which are formed when cooled air is depositing its superfluous humidity. He criticizes Bouguer for limiting the altitude of the clouds to 8,000 feet, and says they may exist at 168 miles.

Notice of Clouston's Explanations of Weather Prognostics (same vol.).

(*Page* 93.) Easterly gales without rain during the spring equinox foretell a dry summer. Dr. Kirwan's rules, verified by Howard in 1808, are (1) when there has been no storm before or after the vernal equinox the ensuing summer is generally dry, at least four times in six; (2) when a storm happens from an easterly point on the 19th, 20th, or 21st of March, the succeeding summer is dry four times in five; (3) when a storm rises on the 25th, 26th, or 27th of March, and not before, in any point, the succeeding summer is generally dry four times in five. Dry summers, Dr. Kirwan says, are a consequence of uniform winds, from whatever quarter they may blow; as wet summers are of variable winds, particularly in opposite directions.

1868.

Buchan, A. *A Handy Book of Meteorology.* 2nd Ed. (*rv.*)

(*Page* 35.) It is probable that the vapour of water exerts a pressure on the barometer in another way than by its elastic force. The maximum barometric (*Page* 36) pressure in the forenoon is brought about by the rapid evaporation arising from the dryness of the air and the increasing temperature, together with the overflow of air in the upper regions of the atmosphere from the wave of heat which (*Page* 39) has been going on for some hours. In the neighbourhood of the equator, where the temperature and moisture differ little in the course of the year, there is little variation in the mean pressure from month to month. Thus at Cayenne the (*Page* 40) pressure in January is 29·903 in., and in July 29·957 in. The low winter pressure at Reykjavik, Sandwick, and Sitka is due to the comparatively high winter temperature, the large amount of moisture in the air, and the heavy (*Page* 47) rainfall. The July distribution of atmospheric pressure is due primarily to temperature, and secondarily to the moisture of the atmosphere. The effect of the Mediterranean, Black Sea, Caspian Sea, North Sea, and Baltic Sea, in deflecting and otherwise determining the position of the curves of pressure is very interesting. Air charged with vapour of water is considerably lighter than dry air; consequently when moist air accumulates over any region an ascending current takes place. But as moist air ascends into the upper regions of the atmosphere, it is cooled below the point of saturation, condensation follows, and rain is precipitated. In the act of condensation heat is liberated which, by heating the air in the higher parts of the atmosphere, tends still further to diminish the pressure, and so accelerates the ascent of the current. This influence of the vapour on the isobarometric curves is illustrated in Plate I. [not given here]. In the North Pacific, where at this season the two trade (*Page* 50) winds meet and mingle, there occurs a belt of low pressure caused by the vapour accumulated by these constant winds. In the Atlantic at 15° N. lat. there is a similar belt of low pressure, at least lower than what prevails to the north and south of it. The crowding together of the isobarometric lines in the south and east of Asia is caused by the vapour which the summer monsoon brings to these regions, and which is there precipitated in a copious rainfall. The low pressures which prevail during all seasons in the Antarctic Ocean are no doubt due to the saturated state of the atmosphere resulting from the N.W. winds, which blow thither from an almost unbroken sheet of waters which embraces the S. Pacific, the S. Atlantic, and the Indian Ocean, and which meet with little land to condense the (*Page* 52) vapour till they flow within the Antarctic Circle. Two of the January areas of diminished pressures are caused by there being vast reservoirs of moist air—

viz., the north part of the Atlantic and the north part of the Pacific, and the parts (*Page* 55) of the continents adjoining. The influence of high temperature in lowering the mean annual pressure over any portion of the earth's surface is slight, as compared with the depressing influence of the vapour of the atmosphere. It may therefore be concluded that the chief disturbing influences at work in the atmosphere are the forces called into play by its aqueous vapour—thus giving to this element a paramount claim on our regard in studying winds, storms, and other (*Page* 95) atmospheric changes. The quantity of dew deposited is in proportion to (*Page* 124) the degree of cold produced and the quantity of vapour in the air. Illustrations of this [that is the effect of mountain ranges in drying winds and thereby increasing radiation to the leeward, so as to make the temperature range greater] (*Page* 129) are afforded by Norway and Sweden and the British Isles. In summer (*Page* 131) the interiors of continents are hotter and drier. When an area of low pressure is bordered on either side by an area of high pressure, long-continued rains occur in the area of low pressure, while on the southern side the weather is close (*Page* 148) and warm. Though in exceptional cases the amount of vapour indicated by hygrometers may be wide of the mark, yet, in long averages, a very close approximation will be obtained, except in confined localities, which are exception-(*Page* 153) ally damp or exceptionally dry. Professor Elliott remarks that (*Page* 154) moss can retain five times its weight of water on the surface of the soil always prepared for evaporation, and prepared in the manner that it can most readily evaporate. No one need be astonished at the coldness of our hills and the dampness of our mountain climate when they consider that the surface of the soil is either moss or grassy turf. This moss or turf retains most of the water that falls from the clouds, permitting little, except in very wet weather, to enter the soil; this water is almost immediately evaporated, and the turf prepared to receive other supplies. The coldness caused by evaporation must therefore be very great. It follows from this that the conversion of a swamp or a low-lying damp piece of ground into a lake will add materially to the dryness and amenity of the climate of the surrounding district, and the rainier the locality the greater will be the advan-(*Page* 171) tage gained. Dr. James Bryce notices that occasionally a cloud is formed at Brodrick at the point where Glens Rosa and Shiraig meet. The explanation is the (*Page* 186) same as that of the cloud formed at Bowhill. Rain sometimes falls from a cloudless sky. Sir C. Ross describes a case which occurred near Trinidad, December 25th, 1839. It was a beautiful clear night, not a cloud to be seen, yet there was a light shower of more than an hour's continuance. The temperature of (*Page* 212) the dew-point was 72, of the air 74. Differences of atmospheric pressure, and consequently all winds, arise from changes occurring either in the tempera-(*Page* 213) ture or in the humidity of the air. If the atmosphere of one region become more highly charged with aqueous vapour than the atmosphere of surrounding regions, the air of the more humid atmosphere being on that account lighter will ascend, while the heavier air of the drier regions will flow in below and take its place. And since part of the vapour will condense as it descends and heat be thereby disengaged, the equilibrium will be still further disturbed. It is in this way that all the more violent commotions of the atmosphere, gales, storms, hurri-(*Page* 225) canes, and tempests originate. J. K. Laughton lays too much stress (*Phil. Mag.*, 1867) on the condensation of vapour as the cause of wind. Winds are the simple result of differences of pressure, whether such differences be caused by temperature, or from the presence of aqueous vapour or from its condensation. (*Page* 232) An inquiry into the disturbing influences caused by evaporation and unequal temperature as compared with the surrounding land would be a valuable contribution to meteorology—such, for example, as a statement of the local and other causes by which the direction of the winds in January is N.E. at Christiania

(*Page* 282), whilst at Skudesnes, Christiansund, and Hammerfest, the mean direction is S.S.E. For a theory of storms to be satisfactory, it must account for the saturation of the atmosphere with vapour, often over a most extensive region which must be considered as the necessary precursor of storms. How can we account (*Page* 283) for the first part of the course of the West Indian hurricanes, which is at right angles to the prevailing trade winds of that region? Dr. E. Lommel has shown (*Page* 321) that in passing through different thicknesses of vapour, the blue rays of light are first absorbed, then the yellow, and finally the red. When the sun is high in the heavens the thickness of the vapour screen between the sun and the eye is (*Page* 322) not sufficient to produce any perceptible action on the rays of light, which consequently appear white; but as the sun descends to the horizon, the thickness of the vapour is greatly increased, and at sunset it is calculated that the light of the sun has to pass through two hundred miles of air in illuminating a cloud a mile above the earth. Hence, as the rays fall more and more obliquely on the clouds, they appear successively yellow, orange, and finally red. The varied colours of the sun at sunset are caused by the clouds appearing at different heights and in different parts of the sky, so that various thicknesses are interposed between them and the sun. At dawn the clouds first appear red, but as the sun rises higher the yellow light ceases to be absorbed, and the clouds appear orange, yellow, and finally white. It is evident that a high red dawn may be regarded as prognostic of settled weather, because the redness seen in clouds at a great height, while the sun is yet below the horizon, may be occasioned by the great thickness of the vapour screen through which the illuminating rays must pass before reaching the clouds, and not to any excess of vapour in the air itself. But if the clouds be red and lowering in the morning, it may be accepted as a sign of rain, since the thickness (*Page* 323) traversed by the illuminating rays being now much less the colour must arise from an unusual amount of vapour in the vesicular state and in the state intermediate between the vesicular and the gaseous, when the yellow and red rays (*Page* 325) pass. The time of diminution of atmospheric polarisation occurs in the earlier part of the day, when vapour is carried by the ascending currents into the higher regions of the atmosphere by which the cumulus cloud is formed, and no doubt higher up invisible crystals are deposited similar to those of the cirrus; and the period of increase occurs towards evening when the temperature of the lower (*Page* 326) stratum of air is falling, and the ascending currents having ceased, the cumulus clouds are dissolving and the quantity of invisible crystals likewise diminishing. Thus the maximum of polarisation occurs at that time of the day when the air is least encumbered with the invisible crystals of ice and the minimum when the crystals are in greatest abundance. From the above results, especially those showing the influence of the different state of the aqueous vapour of the air on its polarisation, we see the importance of this property of the atmosphere as a branch of meteorology; when the subject has been more widely observed and the law of its modification by the presence of aqueous vapour is more accurately known, it is probable that the knowledge may be turned to excellent practical account, in giving the earliest indication of the commencement of the saturation of the air in the upper regions, and inferentially of the approach of storm and of the rainy season (*Page* 331) within the tropics. If, after an unusual prevalence of S.W. wind, the N.E. wind should set in, it is probable that easterly winds will prevail. If the season be summer, the weather will become dry, warm, and bracing, particularly if the (*Page* 332) wind be E. or S.S.E. If easterly winds preponderate largely above the average in spring, the summer is likely to be characterized by S.W. winds with much rain and moisture; but if easterly winds nearly fail in spring they are likely to prevail in summer, bringing in their train dry, warm, bracing weather, clear skies, and brilliant sunshine. Sir John Herschel, in his 'Familiar Letters,'

states that the moon has a tendency to clear the sky of cloud and to produce not only a serene but a calm night when so near the full, as to appear round to the eye. William Ellis examined the records at Greenwich from 1841 to 1847, and shows that such a striking effect does not exist. The popular opinion probably arises (*Page* 333) from the circumstance that the clearing of the sky near the time of full moon arrests the attention, whereas the clearing of the sky when the moon is not present is less likely to be noticed. Park Harrison has shown that shortly after full moon there is a tendency to dispersion of cloud, which though not very marked is yet very appreciable. Dr. Arthur Mitchell, in his 'Prognostics,' states that the farmers of Berwickshire say that when a long strip of cloud they call a salmon or Noah's Ark stretches in an E. and W. direction it is a sign of stormy weather, when in a N. and S. direction it is a sign of dry weather, or, as a weather saw has it—

'North and south the sign o' drought,
East and west the sign o' blast.'

When the cirrus cloud stretches from north to south, or more correctly from N.W. to S.E., atmospheric pressure is at the time, at least, in regions immediately surrounding Great Britain at the normal height, and there being thus no disturbance indicated, drought or settled weather may be looked for as the barometric pressure in Europe is about the average. But when the cirrus stretches in bands lying E. or W., or from S.W. to N.W., there is great atmospheric disturbance indicated pointing to a system of low pressure somewhere to the W. or S.W., from which a column of moist air is ascending and flowing as an upper current over Great Britain, and from experience we know that this current will ultimately prevail lower down, saturating the air as it descends in preparation for the storm which is advancing. The pocky cloud described by Dr. Clouston is stated to be followed invariably by a storm in about twenty-four hours. Its lower edge must be well defined, for a similar cloud with the lower edge of the festoons shaded away is followed by rain only. This cloud is probably caused by large volumes of saturated air forcing their way through drier and colder air, the form of this cloud suggesting moist air diffusing itself horizontally or from above, just as the formation of the cumulus indicates diffusion upwards. If this supposition be correct it shows the moist warm current to be of greater strength than usual, and a sudden commingling of air currents, differing widely in temperature and degree of saturation.

Buchan, A. *Journ. Scot. Meteorol. Soc.*, vol. ii. (1869), No. for October 1868 (*rvp*).

(*Page* 208.) Of the causes which render the atmosphere specifically lighter, and therefore lower the readings of the barometer, may be stated an excess of vapour over a restricted region, or the withdrawal of vapour from the atmosphere where it is condensed into rain or snow. Observation indicates that the greatest quantity of vapour at any place occurs immediately in front of a storm, the amount increasing as the barometer falls ; and that immediately after the storm has passed, or as soon as the rear of the storm begins to advance over a place, the quantity of vapour rapidly, and in some cases suddenly, diminishes. Now since air when it contains a (*Page* 209) considerable amount of vapour is specifically lighter than air which contains less, there is presented in the front part of storms, as compared with what prevails in contiguous regions, a disturbing cause, which, by making the whole mass of air lighter, necessitates an ascending current. Charts show that in storms the centre of the clouded and rainy region approximately corresponds with the space of least pressure, or to state it more accurately, it lies a little to the east of the place where barometers are lowest. When vapour is condensed into drops which fall as rain or snow, its pressure is withdrawn from the air ; and, for a time, a diminution

of pressure proportional to the amount of vapour abstracted is the consequence. But in the act of condensation latent heat is given out, which, by passing into the surrounding air, maintains a higher temperature in the ascending currents than could otherwise hold good. Thus the tendency of cloud and rain is to lower the (*Page* 200) barometer, and so bring about the disturbance of the atmosphere which we see prevailing everywhere in storms.

F. R. H. *Symons's Meteorol. Mag.*, vol. iii. (*rsp.*)

(*Page* 102.) While we were in Abyssinia—February, March, April, and May—the sky was invariably clear from dawn to noon ; but at some time during the afternoon, in the later part of the season, clouds appeared in the sky, and this occurred with a most remarkable punctuality. It was evident to us that at the same place the phenomenon would occur day after day at the same time within an hour or so. There was often mist at dawn, but this mist was soon dispelled by the sun, and only precipitated at all on three occasions. This would be merely a local accident, and may be neglected. But the daily punctuality of the gathering clouds from which we often got a hail or rain shower could not pass unnoticed. This was no peculiarity of the year we were there, for mention of rain frequently occurs in the statements of travellers over the same ground at the same time of the year, and almost invariably towards the end of the day's march, which would naturally be between 3 and 6 P.M. While we were along the Eastern Highland I believe the wind was constant from E.N.E., or N.W., although it was often deflected by the hills and valleys. This being the case, of course it brought with it from the lowlands, or perhaps even from the sea, vapour, which would be precipitated on striking against the lofty mountains. Hence the punctuality and also the reason of rain not falling in the morning. For during the night the evaporation would not take place in any considerable quantity. Perhaps it would be possible to calculate from whence the major part of the vapour came by noting the speed of the wind and the time of the arrival of the vapour which formed cloud on striking the mountain tops.

Gritton, F. B. *Symons's Meteorol. Mag.*, vol. iii. (*rsp.*)

(*Page* 106.) Sir J. Herschel, in *Good Words* for 1864, says that a clear sky and a serenity of weather at night are the usual accompaniments of the period of full moon, a tendency of which we have assured ourselves by long-continued and registered observations. (Editorial. Ellis finds from observations made every two hours day and night at Greenwich during seven years, 1841-47, that Herschel's theory is unsupported. Arago says, 'La lune mange les nuages,' and our sailors say, 'The full moon eats up the clouds."

Luck, Richard. *Symons's Meteorol. Mag.*, vol. iii. (*rsp.*)

(*Page* 106.) I have noticed in North Wales that before a coming gale of wind the light clouds are, especially soon after sunrise, brilliantly illuminated with gorgeous orange colour. What is the connection between them ?

Lyell, Sir C. (*B.* 1868, 5.)

(*Page* 496.) Peat only grows in moist places having a sufficiently low temperature.

Mann, R. J. *Journ. Roy. Geog. Soc.*, vol. xxxvii. (1868) (*rs*).

(*Page* 57.) The summer in Natal is a season of very frequent cloud. The summer heat is tempered by cloud screens and constant evaporation. The winter is a season of almost constant sunshine. At the Cape of Good Hope the summer is dry (*Page* 58) and the winter wet. Almost every day in summer gets cloudy soon after noon, and the clouds continue to shroud the sky and screen the ground until far into the

night, when the sky clears. The mean humidity at Maritzburg at 9 A.M., based on (*Page* 63) eight years' observations, was 71·2 ; at 3 P.M., 60·1 ; and at 9 P.M., 8·34 ; mean for the year 70·8.

Raimondi, Ant. *Journ. Roy. Geog. Soc.*, vol. xxxvii. (1868) (*rs*).

(*Page* 121.) The town of Ayapata in Peru is subject to neblina, or mist, generally towards the evening. It is so dense that objects are not to be distinguished a few paces off. Nearly all the towns situated on the eastern slope of the great chain, and between 8,000 and 12,000 feet above the sea, have this visitation of the neblinas. The phenomenon is owing to the currents of air being in one direction during the day and in another during the night. In the morning the elevated portions are free from mist, but the lower and hot parts are then filled with a dense stratum o vapours. The elevated portions of land being at these hours first exposed to the sun are heated, and a current of air from the lower and hot parts is thereby caused, and the vapours are carried from below upwards, and are dissolved in the higher regions owing to the sun having heated them. In the evening the atmosphere (*Page* 122) becomes cold, and the vapours are condensed to form the neblinas. At night a down current is set up by the cooling of the lower regions, the mists fall as water, leaving the air clear.

Strachan, R. (*B.* 1868, 11.)

(*Page* 18.) The forecasting of cloudy, overcast, or clear sky must be rather a matter of shrewd guessing than an application of any definite rules.

Symons's Meteorol. Mag., vol. iii. (*rsp.*)

(*Page* 111.) The observer at Derby remarks on the absence of dew at that place during July arising from the dryness of the air, hot nights, and bleached condition of the grass (colour being an element in its formation).

(*Page* 118.) Fournet, in 'Commission Hydrométrique et des Orages,' 1866, notices that during stormy weather the S.W. winds arrive in the Rhône department almost saturated with vapour, which at times produce detached clouds around the mountain tops ; at others banks of clouds, whose thickness varies, according to the intensity of the operating causes. In either case, owing to the currents of air, these clouds are so elongated that they may for distinction be called 'storm columns,' from their resemblance to columns of troops. Sometimes it happens that these bands are dissolved in passing from the mountains above the plains, while if the atmosphere is nearly saturated the elongation becomes considerable, and as our (*Page* 119) mountain tops are close together the celestial vault is carpeted with these columns, which remain parallel among themselves in a S.W. N.E. direction ; lastly, if they are in a state of saturation, the vapour is condensed all along the bands ; then also a very large dense and low stratus is formed, rain falls throughout, but traces of the column arrangement remain. Occasionally bands are formed from N. to S., when prolonged thunderstorms reign amid the peaks of our western mountains. Sometimes the phenomenon is confined to the S., sometimes to the N., and sometimes one or two bands alone are formed. Among the many interesting phenomena connected with these columns motion is but one ; the unequal distribution of wind force, of lightning, and of vapour often appearing at intervals like waves, fully merit the notice of meteorologists.

(*Page* 194.) C. Meldrum, in his 'Meteorology of Port Louis,' in the Mauritius, notices that the curve of elastic force of vapour harmonizes exactly with that of temperature. The air is driest (63·6) at 1 A.M., and most humid about 3 P.M. (69·9). During seven years the air was never saturated, the nearest approach being 96·7 on August 21st, 1860. He refers to the double maximum and minimum of atmospheric pressure and to Dove's explanation. But he finds that at Mauritius the

pressure (exclusive of the assumed vapour pressure) has a progression similar in all respects to that of the total pressure. Therefore, the phenomenon in question cannot be accounted for by the direct action of the vapour pressure. The nights (*Page* 195) and mornings are comparatively cloudless ; towards 10 A.M. the clouds gather ; by 2 P.M. it is often wholly overcast, and in the evening clear again. The mean amount of cloud is 4·7.

1869.

Brumham, G. D. *Symons's Meteorol. Mag.*, vol. iv. (*rsp.*)

(*Page* 56.) The position of the moon in the equator with regard to our [British] meridian has an important influence on drought. The rules are :—1. When on any day between the middle of March and the middle of September the moon reaches perigee or apogee in the afternoon within about an hour (say seventy minutes) of the time she comes to our meridian (and here I may say that the southing must occur in the afternoon, or at any rate at not more than twenty minutes after midnight) a long period of deficient rainfall will occur about that time or set in a few days afterwards. 2. In any year when lunar perigee occurs entirely or very frequently (*Page* 59) in south declination, if the moon crosses the equator on some day between March and October, within fifteen minutes of her southing, a long period of drought will set in (if it has not already commenced) shortly after the day when these latter phenomena occur. [A table is given of all the instances which have occurred of these two laws since 1833, with descriptions of the weather which was associated with them in South-east England.] When the sun reaches perigee within forty minutes of noon or midnight, the succeeding summer has always several months of very dry weather, and the rainfall of the period from March to September inclusive is always below the average. [All the instances which have occurred since 1833 are given.] The foregoing rules appear to be very infallible.

(*Page* 59.) According to the law, fine weather for harvest should set in soon after August 9th, and be dry for a long period. There should also be a month of deficient rainfall in the latter part of May.

[These notes, of course, refer to rainfall, but as they indirectly indicate dryness of the air they are entered here.]

(*Page* 88.) I did not regard the slight deficiency of rainfall noticed by Mr. Ryves as evidence of drought. There may be drought with an average rainfall, as by drought is meant a number of days in succession without rain. My rules refer to (*Page* 89) my district, and are correct for it. I do not know how other districts may be affected by them.

(*Page* 107.) I should have mentioned that in 1868 lunar perigee occurred in our meridian on March 5th. This may have inclined the weather to drought.

(*Page* 108.) There are other causes of great drought, such as great heat. The principle of uniformity with regard to the moon's positions near the equator (in December, January, April, or May) appears to cause a high summer temperature, and in that way to influence the rainfall. For instance, on April 20th, 1868, the moon at midnight was 0°45′ north of the equator, and on May 3rd she was 46′ south of the equator at the same time. The period of great heat and drought which set in about the end of April appears to have been caused by this uniformity. The instances that have occurred since 1766 are rare, but in every case great heat and drought accompanied the lunar phenomena. 1788, 1800, 1807-8, 1818, 1826, 1842, 1859, and 1868 were the only years in which this particular lunar uniformity occurred, and each year gave us a summer of great heat and drought. In 1846, 1857, 1859, and 1868 another kind of lunar uniformity occurred, and these years also gave us intense heat and much dry weather.

Buchan, A. *Journ. Scot. Meteorol. Soc.*, vol. ii. (1869), No. xxiv., October 1869 (*rvp*).

(*Page* 342.) In Scotland the monthly curve of lightning without thunder roughly (*Page* 343) follows the curve of relative humidity.

Griffith, C. H. *Symons's Meteorol. Mag.*, vol. iv. (*rsp.*)

(*Page* 40.) Which is the correct way of computing mean daily humidity? By using Glaisher's tables at low temperatures I sometimes get a much greater mean temperature of the wet bulb than of the dry. Thus on October 24th I had—

9 A.M.		3 P.M.			
Dry Bulb.	Wet Bulb.	Dry Bulb.	Wet Bulb.	Max.	Min.
45·6°	45°	55·4°	55·3°	60·2°	38·4°

Max. 60·2° } range 21·8°
Min. 38·4 }
Sum. 2)98·6
Mean 49·3
Corr^n. from Table 0·9
48·4 mean from max. and min.

	Dry Bulb.		Wet Bulb.	
	9 A.M.	3 P.M.	9 A.M.	3 P.M.
	45·6°	55·4°	45·0°	55·3°
Corr^n. from Table III.	0·2	7·4	0·8	3·9
	45·4	48·0	44·2	51·4
	2)93·4		2)95·6	
	46·7 mean from dry bulb.		47·8 mean from wet bulb.	

Home, D. Milne. *Journ. Scot. Meteorol. Soc.*, vol. ii. (1869), No. xxiii., July 1869 (*rvp*).

(*Page* 313.) Baddeley says when whirlwinds are running about white patches of cirro-cumulus are frequently seen in the clear blue sky exactly resembling flakes of teasled cotton, having rotatory motions throughout, forming and then rapidly dissolving, or ascending with whirling motions in the upper regions.

Kesteven, W. B. *Symons's Meteorol. Mag.*, vol. iv. (*rsp.*)

(*Page* 179.) The dry bulb is generally from ·5° to 1·5° too low, owing to evaporation of moisture condensed on it from a very moist air.

Ryves, G. T. *Symons's Meteorol. Mag.*, vol. iv. (*rsp.*)

(*Page* 67.) Mr. Brumham's rules do not seem to be infallible. He regards ·03 in. [·3 in. Ed.] deficiency of rain as evidence of drought; and this rule should, but does not, apply to all places in the same meridian. In the summer of 1868 it was dry here, but in South Europe it was exceptionally wet and cold. At Rome we find June and July were wet and cold; August and September scarcely warm; November and December wet, cold, and foggy. The difference of meridian from Greenwich is not more than fifty minutes. Hence the moon was within fifty-five minutes of its southing at Rome, and the case was fairly within Mr. Brumham's rule. Scotland has the same meridian as England, yet we sometimes have extreme wet there, while South England is exceptionally dry.

Stewart, Balfour. *Symons's Meteorol. Mag.*, vol. iv. (*rsp.*)

(*Page* 153.) The amount of vapour present in the air affects the skin of the human body and the leaves of plants; but I am not aware that it has yet been determined by the joint action of naturalists and meteorologists what is the precise physical function which expresses proportionately the effect of moisture upon animal and vegetable life. Is it simply relative humidity? or does not a given relative humidity at a high temperature have a different effect from that which it has when the temperature is low? I will, however, here consider the matter from the physical science point of view. As such it is one of our objects to ascertain the distribution

and laws of motion of the dry and wet components of our atmosphere; and it cannot be denied that at the present moment we are in very great ignorance of these laws. As we cannot trace the motions of individual particles of air, or vapour, we must arrive at it indirectly, by frequently ascertaining the amount present at any one station at any moment. The best way of measuring the amount is the mass of vapour present in a cubic foot of air. With regard to the motion of the atmosphere, and of the vapour, we can gauge the mass of air and the mass of vapour passing a station horizontally. We have no means of getting at the vertical motion, and we (*Page* 154) must detect this indirectly. We ought also to determine the production or consumption of the vaporous element of our atmosphere as it passes from place to place. This might be done could we keep an accurate account of the evaporation and the precipitation; but this would be a very difficult operation. To recapitulate we can now determine—1. The mass of vapour actually present at a station from hour to hour. 2. The mass that passes a station in one hour going east and west. 3. The same going south and north. There are wanting 4. The vertical component of the motion of vapour. 5. Its production or consumption as it passes from place to place. These deficiencies may be, to some extent, overcome by the following considerations. First, the atmosphere moves as a whole when it moves, the dry and moist air moving together; secondly, dry air is neither capable of production nor of consumption, but always remains constant in amount. To illustrate this part of the subject, let it be supposed we wish to investigate the vertical motion of the atmosphere at a certain station. Make this station the imaginary centre of a circle, the circumference of which may be supposed to be studded with other stations at sufficiently frequent intervals so that we can tell hour by hour how much dry air passes in towards the centre, and how much passes out away from it. Suppose more air passes in than passes out. But if we find a diminution in the stock of air at the centre, some must pass upwards and carry the vapour with it. Now as to the vapour. The hygrometric quality of the air may be represented by—

Mass of vapour in a cubic foot.
Mass of dry air in a cubic foot.

This quotient can only alter by evaporation, or by precipitation, or by mixture. The hygrometric quality of the air may perhaps be considered as a quality sufficiently constant to aid us in tracing the actual motion of the air. But besides this aid we may make use of it to enable us to tell the precipitation or evaporation. For instance, a very damp air in passing over a very dry country may be supposed to emerge less damp, having its hygrometric quality changed, and so with regard to dry air traversing a damp country, the change being in the opposite direction. Thus by actual observation of the quality of the air at the time of its reaching some particular tract of land or ocean, and at the time of its leaving it, we may possibly get much better observations of what goes on in the country, as far as this particular (*Page* 155) research is concerned, than if it were studded with gauges. Meldrum suggests that summaries should be given of the aggregate wind in definite directions, and Airy suggested that the phenomena could be best studied when the wind was constant in the same direction for a long period.

Stow, F. W. *Symons's Meteorol. Mag.*, vol. iv. (*rsp.*)

(*Page* 85.) The drought in 1868 began in April, and wet weather set in on August 6th. But Mr. Brumham claims it was dependent on the position of the moon on July 20th. This is like putting the cart before the horse.

Symons, G. J., and R. Field. *Symons's Meteorol. Mag.*, vol. iv. (*rsp.*)

(*Page* 132.) They notice the variable results given by the observers of evaporation, 11 in. in one case, and 48 in. in another, for the same year; and they

condemn the method proposed by Daniell. The chief source of error is the abnormal heating of the water in the evaporators. They made a series of experiments on the canal of Burgundy in large tanks, and found the amount to be half that generally assumed. More reliable instruments are necessary.

Symons's Meteorol. Mag., vol. iv. (*rsp.*)

(*Page* 65.) Would it not be an advantage if a few observers would concentrate their attention on the character of the sky as indicative of weather? Clouds should (*Page* 66) be methodically observed and the observations reduced to a tabular form, as for instance, thus :—On left-hand page of a foolscap-sized book rule 16 columns for—1, date ; 2, hour ; 3, temperature ; 4, barometer ; 5, wind direction ; 6, wind force ; 7, rain ; 8, amount of cloud ; 9, forms of cloud ; *a*, cirrus ; *b*, cirro-cumulus ; *c*, cirro-stratus ; *d*, cumulus ; *e*, cumulo-stratus ; *f*, stratus ; *g*, nimbus ; *h*, scud. The (*Page* 84) proportion of sky occupied might be given as nearly as can be estimated. The colour of the sky is modified by the combination of three tints—viz., the blue, which is reflected by the particles of air ; the black of space ; and the white of the vesicles of fog and flakes of snow. The blue rays are darkened by the one, and lightened by the white of the vesicles of fog. When we ascend in the atmosphere we leave a great portion of the vesicles of vapour beneath us, so that while the rays reach the eye in less proportion, and the sky being covered with a lesser number of particles reflecting its light, the colour becomes of a deeper blue. For the same reason the blueness of the horizon is less intense than at the zenith. If the sky is paler in the open sea and in high latitudes than in the interior of the continents and in the neighbourhood of the equator, it must be attributed to the vesicles of fog.

Wild, H. (*B.* 1869, 12.)

(*Page* 294.) When objects in the distance are obscure and hazy, it is regarded as a sign of fine weather, but when they come out unusually distinct it is considered to be a sign of approaching rain. De la Rive's explanation is that the air is rendered opaque by the presence of dust and vegetable germs. When the S.W. winds blow the air becomes moist, the corpuscles absorb moisture, and being rendered heavier, fall to the ground, leaving the air more than usually transparent. Marshal Vaillant explains the difference by the greater or less prevalence of vertical air currents.

1870.

Ansted, D. T. *Physical Geography*, 4th Ed., 1870.

(*Page* 59.) Area of water is 145 million of square miles. Water area north of (*Page* 61) the equator equals 59 millions of square miles ; south of the equator, (*Page* 150) 86 millions of square miles. The excess of evaporation above rainfall is (*Page* 238) directly or indirectly one of the most important causes of oceanic currents. The sun's heat reflected from the shining moon is absorbed by our atmosphere before it reaches the earth, and thus tends to disperse cloud, and produce (*Page* 271) coolness on the earth by allowing of increased radiation. When rain has recently fallen, it is often curious in mountain countries to watch the incessant and rapid formation of cloud over some small wooded patch of land, the moisture from the warm earth steaming into the chilled air, and being immediately converted into mist, which gradually accumulates until it breaks away and drifts to a distance, assuming a distinct cloud nature. It is equally curious to observe a narrow side valley in a mountain district, covered for hours together with mist and rolling cloud, while the larger and more open valley into which it opens has a perfectly clear sky. The cause of this is obvious. The lateral valley, enjoying less of the sun's rays, is colder than the more open valley adjacent ; the air as it passes is

therefore sucked up the side valley, and coming into the cooler temperature of its sides is at once condensed into mist. Such mist may often turn into cloud. The clouds below 10,000 feet are more massive than those above, and are more influenced (*Page* 272) by local causes. The quantity of vapour existing in the air in an invisible form depends on local temperature, and is probably at no time uniform over any considerable area, and certainly never the same for twelve hours together in the same place. It is found that when the temperature is 50° F. each cubic yard of dry air (about 168 gallons) can hold nearly 150 grains of water; at 32° F. (*Page* 273) only half this; and at 70° F. nearly double. Condensed vapour has a tendency to assume the form of the object by which it is caused. Thus, when mountains are present, a cloud seems to fix itself at the summit or on the sides of the mountain at a certain level, and there obstinately remain, as on Table Mountain and Mount Pilate. The warm wind loaded with moisture is chilled. The chill commences a short distance to windward of the object, and continues at a distance to the leeward of it, until the air is no longer affected by the cool surface it has (*Page* 274) been in contact with for a time. The cloud is a driving mist. At the equator Humboldt observed the general direction of cirrus clouds to be N. and S. (*Page* 279), but with us they seem more frequently N.W. and S.E. Clouds neither float in the air like boats, nor are they retained only for a short time, like feathers, by friction and resistance; nor do the particles of water in a cloud consist of hollow spheres with void cavities or with their interior filled with light gas. Neither is the water cloud like the cloud of incense that rises and for a time floats in air while disseminating its fragrance. The permanence of clouds is due to the vapour atmosphere being independent, and to the gases diffusing into each other, so that the (*Page* 280) heavier gases are held up by the lighter. The vapour may be set free without assuming a fluid form. It is possible that clouds are limited to air in motion, for it is quite certain that a cloud may appear in repose, even when violent and shifting winds are all around. The conversion of what may be called a dry cloud into a mist seems to be accompanied in all cases with electrical action. Owing (*Page* 285) to the unequal distribution of land in the two hemispheres, the aqueous vapour, which from the autumnal to the vernal equinox is developed to an immense extent in the southern hemisphere, returns to the earth in the other half of the year in the form of rain and snow. Immense physical force is exerted in the evaporation of water from the ocean. The total estimated rainfall is not much less than 200 millions of millions of tons. Hence about 7000 lb. weight of water are (*Page* 286) evaporated every minute, on an average, throughout the air from each square mile of ocean. The conversion of this into vapour, its conveyance through the air, and its recondensation involves an expenditure of force equivalent to the lifting of very much more than 1,500,000 millions of millions of pounds of water, one foot high per minute of time during the whole period. Besides evaporation from the sea, there is also a very large evaporation from the surface of the land. This is a fraction of the real amount of force exerted, for much of the water raised by evaporation falls back as rain directly into the ocean. It is a work going on incessantly, and one that has probably been going on at nearly the same rate during (*Page* 302) all time. By the drainage of land and the removal of forests, the conditions of a country are so far altered with respect to its rainfall and the moisture (*Page* 306) of the air, that the temperature becomes permanently affected. Cirrus clouds are often the first signs of coming wind and change of weather. In summer (*Page* 307) they announce rain, in winter thaw. When the round heaped clouds appear early in the morning they often gradually disappear as the day advances, and after noon the sky is clear; but when they come on after noon and increase towards evening, they generally terminate in rain. Among signs of fine weather, an early and heavy dew has often been noticed.

Bidie, George. *Journ. Roy. Geog. Soc.*, vol. xxxix. (1870). Paper read January 25th, 1869 (*rsp*).

(*Page* 78.) In the shade of the dense jungle forest of Coorg there is a dense undergrowth of moisture-loving plants, such as cardamom, canes, areca, plantain, tree and other ferns, wild pepper, arums, and orchids. The rain in (*Page* 79) Coorg mainly comes from the S.W. monsoon, which is the S.E. trade wind deflected westerly by the diurnal rotation of the earth, and as this passes over an immense expanse of ocean ere it reaches the land, it becomes heavily charged with moisture in its course. The presence or absence of forests can have no appreciable influence on the amount of rainfall. At the same time, it must be stated that the natives of Coorg complain that of late years their country has become hotter and drier from want of rain, and that rice crops have been diminished or lost from a failure of water in streams that used to run throughout the year. These changes they attribute to the cutting down of forests on coffee estates. It is (*Page* 80) only since the advent of the European planters, or during the last twelve years, that felling of forests to any considerable extent has taken place in Coorg, and as the clearing has progressed in annual instalments of comparatively small extent, the results have crept on gradually. There can be no doubt, too, that the evil influences called forth by forest destruction do not attain their full force immediately, but go on increasing from year to year until they acquire a most disastrous power. The spots that have been selected as sites for estates are chiefly situated on the flanks and crests of low hills, the sides and bottoms of ravines, and the slopes and passes running down on the west side of the Ghats to the low country. Such localities are, as a rule, densely wooded, and being well supplied with springs, give rise to numerous small streams. In fact, they may be looked upon as the fountains of the river system of the country. The question then arises, To what extent are springs and streams in such situations dependent on the forests for their supply of water, and what will be the effect on them of its removal? Springs and small streams are fed by the water stored up in the earth during the rainy season. As the rain descends on natural forests, it is conveyed in various directions by the leaves towards the ground, and on reaching this is prevented from running rapidly off by the dense undergrowth of shrubs and herbaceous plants, and a carpet of dead leaves. Below this it encounters a layer of vegetable mould, which, having a great affinity for moisture, absorbs it like a sponge. As soon as the humus is fully saturated, it passes on what water may subsequently fall to the subjacent earth, and this process of percolation is in various ways aided by roots, which descend to great depths, perforating the densest subsoil, and even forming passages in rock. The quantity of water thus transferred to the depths of the earth and the reservoirs of springs is enormous, and when the dry season arrives the forest again plays an (*Page* 81) important part by husbanding and giving off gradually the subterranean supplies. As the water rises, it meets with many obstacles, preventing its collecting into streams and passing rapidly away. Although the quantity of water taken up and exhaled by trees is very great, a proportion of it is returned as dew or fog, and what is wafted away is fully compensated for by other advantages resulting from the presence of forest. The influence of shade in modifying evaporation is well illustrated by what happens in the coffee districts after the April showers, which herald the advent of the S.W. monsoon. On an estate freely exposed, a day or two of sunshine after a heavy fall will have rendered the soil quite dry and hard again, whereas on an estate under forest shade the ground will continue damp for a week or more. Although their insignificance might lead to their being overlooked, there can be no doubt that the mosses, lichens, and succulent herbaceous plants which abound in tropical forests are also of considerable benefit in retaining

moisture, as during rain they absorb water like a sponge, and part with it again very slowly. It would, therefore, appear that there are numerous agents and conditions in natural forests favourable to the production and permanence of springs and streams which are not to be found in open ground, originally so or denuded of its trees by man. The facts thus elicited go far to prove that tropical forest is the *alma mater* of springs and streams. Various instances have been brought to my notice of springs and small streams having become quite dry since the forest was cleared away in their neighbourhood; while in numerous cases, those that used to be perennial only contain water now during, and for a short period after, the monsoon. Similar results have been found to follow the destruction of forests growing near the sources of streams in all parts of the world. Thus Palestine and other Eastern countries have been rendered desolate by the destruction of the forests that existed in them when they were so famous for their beauty and fertility, and in modern (*Page* 82) times many districts in France and America have had their water supply diminished, and fertile land converted into arid wastes, by the clearing away of woods around the head waters of streams. In a recent Mauritius paper it was stated that the culture of the sugar-cane had of late become precarious in the island, owing to the excessive dryness of the air and soil consequent on the cutting down of forests. For several years, too, the nutmeg trees of Singapore have been dying. A most graphic account of the disaster will be found in Cameron's 'Malayan India,' and judging from the information there given as to the cutting down of forests to make way for the nutmeg, and the manner in which the trees died, there seems every reason to believe that their death was accelerated, if not entirely induced, by the reduction of humidity resulting from extensive clearing. The effect of forest-clearing and burning of the undergrowth is to make the soil friable and easily removed, so as to leave the barren stony subsoil (*Page* 85) exposed. The rainfall drains away rapidly. The plants which spring up in neglected clearings are such as grow in hot, dry situations. Forests reduce the temperature of the air chiefly by transpiration. The amount of water exhaled in this way is enormous, a sunflower having been found to give off from 20 to 30 ozs. daily. Although a tree under certain (*Page* 86) conditions will absorb moisture from the air, still the amount thus withdrawn is as nothing compared with what it gives off by transpiration. By a beneficent arrangement, too, the amount of exhalation increases within certain limits in exact ratio with the heat and dryness of the air, and thus the severity of the hot season is partially mitigated. Plants in the immediate neighbourhood of forest, even although enjoying no shade, show by the colour and luxuriance of their leaves that they are living in moister earth and air than those at a distance. As regards the soil, it is always very much damper in forests than in open ground. Forests are of great benefit to cultivated plants in their neighbourhood by promoting the deposition of dew, and causing fog. They also obstruct the passage of drifting fogs, and so make them part with some of their moisture; and when a dry, scorching wind sweeps over a damp wood it is moistened, and rendered much less hurtful to vegetation. Again, when a cultivated valley lies at the base of a forest-clad hill, the moist stratum of air above the trees rolls down the slope to it in calm nights, covering each leaf and blossom with copious dew. That the cutting down of forests in Coorg has rendered both the earth and air there drier is clearly shown by many plants perishing that used to flourish during the dry season, and by other remarkable changes. The most (*Page* 87) remarkable change produced by forest obstruction on vegetation has been the increase in species that formerly grew in hot and barren situations in the province. Thus we have in clearings several kinds of ficus, two macarangas, *Sponia Wightii* (charcoal tree), two solanums, *Clerodendron infortunatum*, *Calli-*

(*Page* 88) *carpa caria*, several grasses, etc., all naturally inhabitants of pasture land. At the same time, several moisture-loving plants, such as ferns, aroideæ, canes, wild plantain, cardamom, etc., have become much less common, or have disappeared in various tracts. The *Solanum rubrum* has become common in some places. *Physalis Peruviana*, an exotic, has also increased in a wonderful manner, growing spontaneously in clearings all over the country. The plant that has been most influenced by forest destruction is the White Weed, or *Ageratum Cordifolium*, which pursues the footsteps of the planter wherever he goes, springing up all over (*Page* 89) his clearings. Forests on the crests or slopes of hills on which important streams arise should always be carefully preserved, and the banks of streams should always, to the distance of twenty or thirty yards on each side, be left under wood, as its presence serves to keep up the water supply in the dry season. The rice lands in Coorg are very peculiar, being long, narrow, winding patches, surrounded by low forest-clad hills, from which they derive their water supply. Forest in the upper end of ravines should also be preserved, as it invariably gives birth to springs and streams.

Chambers, C. *Symons's Meteorol. Mag.*, vol. v., November. Paper read to the British Association (*rs*).

(*Page* 168.) Two distinct causes are assigned for the larger quantity of rain in the lower gauges: first, that damp air transferred by the agency of winds from a warm to a cold district, finds the latter region colder, not in the upper strata only, but also in the lower, and in cooling, has its vapours condensed as well in the lower strata as in the higher. Consequently a rain-gauge placed at any given elevation will catch rain, amounting to the sums of the condensations above it, and, therefore, the lower a gauge is placed the greater will be the quantity of rain it receives. The second cause suggested supposes the particles in the air to be susceptible of electrical induction, and consequently, to be electrically polarized by induction from the ground, which is known to differ in electrical tension at all times from the atmosphere above it. This polarization of the particles of vapour gives rise to mutual attractions between them, and to their successive coalescence forming rain-drops, and the attractions being strongest near the ground the coalescence will there be most rapid. Consequently, not only should more rain be caught by a gauge at a lower elevation than by one at a higher, but the rate of variation with heights of the quantities received should be more rapid near the ground; and this is in accordance with observation. The second cause also seems to explain the greater fall of rain over forest land; and also, in part, the greater fall in mountainous districts, over land without trees, and over plains.

Compton, T. A. *Symons's Meteorol. Mag.*, vol. v. (*rs.*)

(*Page* 22.) At Bournemouth, on February 12th, at 2 P.M., the dry bulb stood at 27·5° Fah., and the wet at 23°, indicating a humidity percentage of 28.

Dines, G. *Evaporation. Symons's Meteorol. Mag.*, vol. v. (*rs.*)

(*Page* 70.) As April has been very favourable for evaporation experiments (with a total rainfall of 0·4 in. on five rainy days), I send you a description of my gauges, with the amount of evaporation from each. No. 1 is 18 in. in diameter, and can be measured to $\frac{1}{500}$ in. It was observed daily every morning. The results were as follows:—

No.	Inches.	No.	Inches.	No.	Inches.	No.	Inches.	No.	Inches.
1	·012	7	·120	13	·140	19	·146	25	·149
2	·078	8	·117	14	·148	20	·173	26	·168
3	·042	9	·153	15	·093	21	·211	27	·213
4	·091	10	·132	16	·109	22	·205	28	·120
5	·090	11	·041	17	·128	23	·251	29	·064
6	·094	12	·087	18	·165	24	·208	30	·068

The temperature of the water varied from 32° to 77° Fahr., that of the water in the river Mole from 39° to 60·3°. No. 2 is 8 in. in diameter, 6 in. deep, and exposed to the air. The measurements are taken with a vertical float and an attached vernier. No. 3 is 5 in. in diameter, 2½ in. deep, and exposed to air. No. 4 is 4 in. in diameter, 2 in. deep, and fixed at the top of the thermometer-stand. The (*Page* 71) outside is covered with felt to keep the temperature more even. No. 5 is a 5-in. Casella rain-gauge. The total evaporation during the month was respectively—

No.	Inches.	No.	Inches.	No.	Inches.	No.	Inches.	No.	Inches.
1	3·816.	2	5·660.	3	6·710.	4	6·370.	5	4·650.

Nos. 2 and 3 were placed by the side of the 18-in. gauge, about 4 ft. from the ground. No. 5 stands by the side of the other rain-gauges, one foot above ground. In Nos. 1, 2, 3, and 4 the water was generally kept ½-in. below the edge of the vessels. No. 5 was rather lower, or about 1 in. The evaporation from No. 3 was 76 per cent. greater than that from No. 1. Had the evaporation during the day only been given, the difference would have been far greater, as whenever the opportunity of observing the gauges twice during the twenty-four hours has occurred, the evaporation from the smaller gauges during the night has been much less than from the larger ones. In 'British Rainfall' 1869, p. 156, it is said that the accuracy of an evaporation is largely dependent on its capabilities of retaining the temperature of the contained water at, as nearly as possible, that of large volumes of water, such as reservoirs, rivers, and ponds, which statement I endorse. One experiment showed this. From water at a temperature of from 90·7° to 85° the evaporation was at the rate of ·015 in. per hour; from water at 62°, the temperature of the room, it was ·0031 in. per hour. During May the evaporation from my gauges was :—

No.	Inches.	No.	Inches.	No.	Inches.	No.	Inches.	No.	Inches.
1	4·927.	2	5·621.	3	6·542.	4	8·111.	5	5·340.

The positions of Nos. 2 and 3 were varied, being sometimes in the earth, and sometimes in water, nearly to the level of the upper rim. The temperature of the water in gauge No. 1 varied from 33° to 84°; that of the water in the river Mole 46° to 66·8°. (See Notes, 1786, Williams, Exp. 2.)

Dines, G. (*B.* 1870, 3.)

(*Page* 79.) Paper on evaporation and evaporation-gauges, read before the Meteorological Society of London. His conclusions are: 1. The greatest cause of evaporation is the movement of the air. 2. Whatever tends to increase the temperature of the air increases evaporation, and *vice versâ*. 3. That which tends to lessen the temperature of the dew-point increases evaporation, and *vice versâ*.

Erskine, St. Vincent W. *Journ. Roy. Geog. Soc.*, vol. xxxix. (1870). Read June 14th, 1869 (*rs*).

(*Page* 245.) On the Bembe the sky was generally clear towards early morning, and until 10 or 11 o'clock; but after that, bank after bank of clouds would blow up from seaward and completely obscure the sun.

Fuller, F. *Symons's Meteorol. Mag.*, vol. v. (*rs.*)

(*Page* 59.) A self-constituted instrument similar to Snell's aneroid hygrometer may be seen at the Charing Cross lift, which is regulated by a thick rope passing along its whole length. The porter in charge will tell you any day what the weather is going to be by the slackness or tightness of the rope.

Poey, A. (*B.* 1870, 14.)

(*Page* 382.) He says, each country, according to its geographical position, has its

own type of clouds. Here the cirrus predominates, there the cumulus, elsewhere such and such forms, which do not exist in other places.

Somerville, M. (*B.* 1870, 17.)

(*Page* 218.) The ocean covers three-fourths of the earth's surface. There is three times more land in the north than in the south hemisphere. The superficial extent of the ocean is probably unaltered. The difference in the composition of (*Page* 223) sea water depends upon local circumstances. Thus the ocean contains more salt in the south than in the north hemisphere, which is supposed to arise from the S.E. trade-winds blowing over a greater expanse of water than the N.E., and causing a greater evaporation. The sea is heated at its surface by the (*Page* 229) direct rays of the sun, which produce a strong and rapid evaporation, especially in the tropical seas of the ocean. It is computed that 186,240 cubic miles of water are annually raised from the surface of the globe in the form of vapour, chiefly from the inter-tropical seas. The enormous quantity of water thus carried off by evaporation in the warm seas disturbs their equilibrium, which is (*Page* 252) restored by means of the currents. There is probably not a drop of water on the earth's surface that has not been borne on the wings of the wind. (*Page* 254) Jets of steam of high tension are frequent in volcanic countries. (*Page* 296) Many salt lakes may be remnants of the ancient ocean left in the depressions of its bed as the waters retired when the continents were raised above its surface. There are more lakes in high than in low latitudes, because evaporation is much greater in low than in high latitudes, and in this respect there is much analogy between the northern plains of the two principal continents. By the (*Page* 306) constant evaporation of their surface lakes maintain the supply of humidity in the atmosphere so essential to vegetation. The evaporation over the (*Page* 314) surface of the ocean is so great, that were it not restored, it would (*Page* 316) depress its level about five feet annually. In consequence of the unbounded extent of the ocean in the south, the air is so mild and moist that a rich vegetation covers the ground, while in the corresponding latitudes in the north the country is barren from the excess of land towards the Polar Ocean, which renders the air dry (*Page* 319) and cold. [See statement at p. 421.] The aqueous vapour is most abundant in the torrid zone, and, like the heat on which it depends, varies with the latitude, the season of the year, the time of the day, the elevation above the sea, and also with the nature of the soil, the land, and the water. The N.E. trade-wind (*Page* 323) arises from the south side of the calm belt of Cancer, and a S.W. wind from its north side. They leave the calm belt loaded with vapour, which is precipitated as they pass into a colder zone. These S.W. winds do not obtain that enormous quantity of vapour while crossing the Atlantic, for they probably give by rain as much as they receive by evaporation ; therefore it can only come from the south hemisphere. The S.E. trade-winds carry the moisture evaporated from the great southern ocean to the equator ; there they rise into the higher regions of the atmosphere, and blow as an upper current in the calm belt of Cancer ; and now, being chilled, they sink down and come out from the north side of the calm belt as the rainy S.W. winds of the extra-tropical north hemisphere. The same reasoning (*Page* 326) applies to the calm belt of Capricorn. The influence of the heated great plains is felt 1,000 miles or more at sea. Thus, though the desert of Gobi and the sun-burned plains of Asia are for the most part north of the latitude of 30°, their influence in producing monsoons is felt south of the equator. In like manner the Central American monsoons of the Pacific are caused by the heated plains of Texas and Utah ; those of the Mexican Gulf by the dry lands of New Mexico ; and the monsoons of the Gulf of Guinea by the sandy deserts of Africa. Similarly, also, the heated interior of Australia causes an indraught of air during the time the sun is

south of the equator, and a N.W. monsoon, caused by the reversal of the S.E. trades (*Page* 334), brings rain to all the north coast. A thick lurid appearance, with dense (*Page* 338) masses of cloud on the horizon, is a harbinger of typhoon. There are about twenty-five millions of square miles of sea in the north hemisphere, and nearly seventy-five in the southern; besides, the zone of the S.E. trade-wind is much greater than the northern, and covers three times as much water, yet the mean annual amount of rain in the northern hemisphere is probably about 37 in., and 26 in. in the southern; for the vapour from the great reservoirs at the equator and the southern hemisphere is wafted by the S.E. trade-wind in the upper regions of the atmosphere till it comes to the calms of Cancer, where it sinks down and becomes a S. and S.W. surface-wind, and then the condensation begins that feeds all the great rivers of the world. Rains, fogs, etc., are much more frequent and irregular on this side of the equator than on the other. Throughout all the countries in the north hemisphere, where observations have been made on the variations of atmospheric moisture, it appears that the air contains absolutely less vapour in January than in any other month of the year, yet at that (*Page* 339) time there is the greatest dampness to our sensations; while in July the air feels driest, although, on account of the heat, evaporation is the greatest. In summer the dew-point is much further below the temperature of the air than in winter, hence the air is drier. When the moisture is abundant and the tension great, which is often the case before rain, the air is very transparent, and distant objects appear nearer, and all their details are more distinctly seen; from this circumstance, the clearer view of distant mountains and headlands indicates wet (*Page* 340) weather. Dew is very abundant on the shores of continents, but it is not deposited on small islands in the midst of large seas, because on them the difference between the temperature of the day and night is not sufficiently great. There is (*Page* 341) very little dew in the interior of continents, except near lakes and rivers. Fogs rarely occur at sea between the parallels of 30° N. and S., that is, over half the globe. The cloud region of the trade winds is from 3,000 to 5,000 feet high, and it is generally higher over the sea than over the land for the same amount of vapour in the wind. In the north temperate zone the cloud region is high over the land and low over the water; and, as a rule, the further inland, the drier the air (*Page* 344) and the higher the cloud region. The equatorial belt of calms lies mostly north of the equator in the Atlantic; in it the winds meet, and, being highly elastic, they ascend, till, by the cold of the atmosphere, they are condensed into the cloud ring which surrounds the earth and overhangs the belt of calms, but leave the sky clear on both sides. New vapour is continually rising to the under-surface of this cloud ring, is condensed, and falls in constant rains. These rains fall during the day, and morning and evening are free from storms. In the belt of calms, the air, being greatly heated by the vertical rays of the sun, ascends, drawing with it the whole mass of vapour the trade winds have brought with them, and which has been greatly added to by the rapid evaporation from the belt of calms. This vapour is condensed as it rises to the line of junction of the lower and upper trades. In countries between 5° and 10° S. and N. there are two rainy and two dry seasons; one which lasts four months, and another which lasts two. Within the tropical belt of calms and rains one period of the year is extremely wet and the other extremely dry, the change occurring at the equinoxes. The monsoon region furnishes another instance of the effect of mountain chains upon the fall of rain. Throughout the whole of that region it is not the sun directly, but the winds, that regulate the periodical rains. That region extends from the east coast of Africa and Madagascar across the Indian Ocean to the north districts of Australia, and from the tropic of (*Page* 346) Capricorn to the face of the Himalaya, the interior of China to Corea, and even round the north of Siberia. In the south hemisphere the rainy

season corresponds with the N.W. monsoon, and the dry with the S.E. The extent of country on which rain seldom or never falls is five-and-a-half million of (*Page* 347) square miles. The prevailing winds are deprived of their vapour by condensation before arriving at the rainless deserts. Between the tropics it rains rarely during the night, and for months together not a drop falls; while in the temperate regions it often rains in the night, and rain falls at all (*Page* 352) seasons. The atmosphere, where rarefied, absorbs all the colours of the sun's light, except the blue, which is its true colour. In countries where the air is pure the azure of the sky is deep; it is still more so at greater elevations, where the density of the air is less, and its colour is most beautiful as it gradually softens the outlines of the mountains into extreme distance, or blends the earth with the sky. When the sun is near the horizon, the atmosphere, on account of its superior density, absorbs the violet and blue, and leaves the yellow and red rays in (*Page* 353) excess; that property, together with the refractive power of the aqueous vapour, which is most abundant near the earth's surface, gives the roseate hue to the early morning, and the gold and scarlet tints to the closing day. The blending of these colours with the blue above produces the beautiful vivid green so frequently seen in warm countries. The last reflected rays of the setting sun are red. The (*Page* 357) electrical state of the air arises from evaporation, condensation, and chemical changes, but the water evaporated must contain matter susceptible of (*Page* 376) chemical action during evaporation. The greater part of the land is (*Page* 381) clothed with vegetation. The periodical phenomena of the appearance of the first leaves, the flowering, the ripening of the fruit, and the fall of the leaf, depend upon the annual and diurnal changes of temperature and moisture, and succeed each other with so much harmony and regularity that, were there a sufficient number of observations, lines might be drawn on a globe approximately indicating lines where the leaves of certain plants appear simultaneously, and illustrating the other phase of vegetation. The gentianella, veronica, and other plants close their blossoms on the approach of rain. Since (*Page* 383) the constitution of the atmosphere is very much the same everywhere, vegetation depends principally on the sun's light, moisture, and the mean annual temperature or heat of summer. Where rain does not fall the soil is unfruitful, but where moisture is combined with heat and light, the luxuriance of the vegetation (*Page* 389) is beyond description. Mosses are found everywhere in damp situations. (*Page* 393) The labiates are remarkable for their aromatic qualities and love of dry (*Page* 421) situations. Beyond Kerguelen Land and Terra del Fuego not a lichen covers the rocks. In the Arctic regions no land has been discovered destitute of (*Page* 426) vegetable life. Rice requires excessive moisture, and a temperature of (*Page* 436) 73·4°. Each soil has its own kind of insects, whether dry or moist, etc. As the rainy and dry seasons within the tropics correspond to our summers and winters, insects appear there after the rains, and vanish during the hot months; the rain, if too violent, destroys them; and in countries where that occurs there are two periods in the year in which they are most abundant, one before and one after the rains. Culex pipiens passes two-thirds of its existence in water. They swarm (*Page* 460) in the Arctic regions. In hot countries reptiles fall into a state of torpor (*Page* 461) during the dry season. Batrachians are aquatic in their early stage. (*Page* 462) Frogs are amphibious. Toads frequent marshy, damp places. Newts (*Page* 463) are aquatic. In sterile, open countries the proportion of venomous snakes is greater than in those that are covered with vegetation. All the crocodiles (*Page* 466) are amphibious, living in rivers or in their estuaries. Alligators are (*Page* 489) most numerous in the estuaries of great rivers. Monkeys chiefly occur (*Page* 494) in tropical forests. The jerboa burrows in sandy deserts. By converting (*Page* 526) the desert into a garden, draining marshes, cutting canals, turning the

courses of rivers, clearing away forests in one place and planting them in others, man has altered the climate, and increased or diminished the quantity of rain. Man's influence on vegetation has been immense, and it is chiefly through his tendency to cut down forest trees that he has produced the greatest amount of change on the surface of the earth. In warm countries, districts which have no clothing of trees, the rainfall descends in sudden deluges, and the dry seasons are excessively prolonged. Thus the violent rain-wash prevents the accumulation of humus, and the surface of the earth is scorched to sterility by months of fierce sun.

Stow, Rev. F. W. *Symons's Meteorol. Mag.*, vol. v. (*rs.*)

(*Page* 180.) The air is generally saturated most of the day during a sea fog here, whatever Dr. Allnatt may say to the contrary. [No place is mentioned, but it is probably near Whitby.]

Strachan, R. *Symons's Meteorol. Mag.*, vol. v. (*rs.*)

(*Page* 73.) Lamont's evaporimeter consists of two bowls connected by a glass tube; one is covered, the other exposed to the air. The tube rests on a scale of 25 in.; it contains an air bubble, which moves along the scale as the water is evaporated from the open vessel.

Symons's Meteorol. Mag., vol. v. (*rs.*)

(*Page* 2.) Snell's aneroid hygrometer is made by a private gentleman at Saltash. It is made of a piece of whipcord, dipped in some solution (salt and water), fastened so as to act on an axle, and kept stretched by a lead weight. W. B. Kesteven tested it. He reports that it is extremely sensitive to the slightest change of atmospheric dryness or moisture, its rise or fall often anticipating change of the barometer and of the wet and dry bulb hygrometer. It is so far uniform in its (*Page* 3) susceptibility that an accurate scale would give indications of humidity in the same way as the dry and wet bulb thermometer. It might be rendered more (*Page* 74) exact than it is. H. C. Russell's table gives the humidity by simple inspection by means of curves. His values agree closely with Glaisher's hygro-(*Page* 75) metrical tables, 4th ed.; but not with the first edition nor with Guyot. It does not give a lower humidity than 40.

(*Page* 93.) The country [England] is suffering from lack of rain for months, yet the moisture has always been close at hand. The upper regions of the air have been abundantly supplied with water. The moist south-westers have blown over the land. The skies have even been for the most part cloud-laden, yet the winds have drifted onward those vehicles of the precious moisture. The moisture-laden air current which comes from over the Atlantic may flow so low that the western hills rob it of its wealth of water, and suffer dry air alone to pass over the rest of the country; or, on the other hand, the south-westers may range so high as to carry the moisture-laden clouds past our isles; or the south-westers may be beaten back through all the summer months by the dry winds from the east, and so a real dryness of the air prevail, as during the exceptional weather of May 1866. Yet it is comparatively seldom that we owe our droughts to such a real dryness of the upper regions of the atmosphere. This is proved by the fact that our summer nights are seldom cold. Tyndall notices, that a day's steady rainfall in a region no larger than Middlesex corresponds to the action of a force capable of raising more than 30,000 million of tons to the height of a mile. All the coal which men could dig from the earth in many centuries would not give out enough heat to produce, by the evaporation of (*Page* 94) water, the earth's rain supply for a single year. But there are few subjects on which meteorology throws less light than on the causes which influence the dryness or wetness of our summers. At times it would almost seem as though the weather of tropical or sub-tropical regions were brought to us with the northing of the sun. But during other summers an irregular variation prevails. The

attempts to discover any traces of periodicity in the recurrence of dry and moist summers have not hitherto been rewarded with success. Nor does there seem to be any evidence that our climate is gradually changing as regards humidity.

[No. for September.]

(*Page* 130.) The observer at Cirencester says the extreme dryness of the weather from January to May has been due to the tendency of the wind to cling to the north.

[No. for October.]

(*Page* 135.) The Report of the Kew Committee states that the staff at Kew continue to make occasional absolute hygrometrical observations, by means of Regnault's instrument, with the view of testing the accuracy of the method of deducing the dew-point from the observations with the dry and wet bulb thermometer.

[No. for November.]

(*Page* 169.) The Rev. R. B. Belcher, in a paper read to the British Association, stated that the explosion on the Mersey of the *Lotty Sleigh* was heard where he lived, a hundred miles off. It was followed by an immense black cloud and heavy rain.

1871.

Chandless, Wm. *Journ. Roy. Geog. Soc.*, vol. xl. (1871) (*rs*).

(*Page* 432.) The following were the results of ten months' observations at Manaos, scattered over several years. The maximum and minimum were those obtained at the regular hours of observation.

	VAPOUR TENSION.	HUMIDITY.
3 A.M.	·796 inches.	92
9 A.M.	·830 ,,	81
3 P.M.	·811 ,,	70
9 P.M.	·833 ,,	88
Mean	·818 ,,	83
Max.	·980 ,,	98
Min.	·602 ,,	42

Dines, George. *Evaporation.* *Symons's Meteorol. Mag.*, vol. vi., pp. 190—192 (*rsp*).

(*Page* 191.) I should prefer Dr. Hudson's Proposition I. to be expressed thus: When air is saturated with moisture, and the water is of the same temperature as the air, neither evaporation nor condensation can take place. I do not like the words "when air is saturated," as they tend to convey a false impression; except as it regards the dew-point, it is a matter of little consequence whether the air is saturated or not. Other circumstances being the same, it is the difference between the temperature of the water and that of the dew-point which determines the amount both of evaporation and of condensation. In paragraph 5, p. 167 (see Notes, 1871, Hudson), a case is supposed, which, in my opinion, cannot exist; air, under the circumstances named, is not capable of abstracting vapour, and, therefore, cannot surrender its previous spoils again; on the contrary, water of a lower temperature than the dew-point will rob the driest air of a part of the small quantity of moisture which it contains; this I have found to be the case by placing water of a lower temperature than the dew-point in the heated air of a drying-room, when I have invariably found it to increase in weight. It is true that in Table 2 of my paper evaporation appears to take place from water when at a lower temperature than the dew-point, but it will be observed that the words "calculated dew-point" are generally used, and the tendency of my experiments was to throw a doubt upon the correctness of the tables used for the determination of the dew-point; further

experiments have convinced me that they generally, but not always, give the dew-point too high, but some anomalies which I have noticed lead me, at times, to doubt if the wet and dry bulbs can ever give more than an approximation to the moisture in the atmosphere. The time at which evaporation commences from water or from any other substance covered with moisture in its relation to the dew-point, can only be determined by the most delicate experiments. To me it has sometimes appeared to differ in different currents of air, but the whole question is beset with difficulties of no ordinary kind, one of which would be to determine the temperature, not of the water, but of its surface, and, at the same time, to get the correct dew-point; the latter at times appears very changeable. It seems that masses of air, very differently charged with moisture, are rolling over the surface of the earth in the same manner as the clouds above, the difference being that they are invisible. Nothing yet said (*Page* 192) shakes my conviction that condensation occurs if the surface temperature of water is below the dew-point, evaporation if it is above.

Everett, J. D. (*B.* 1871, 6.)

(*Page* 353.) The formulæ used for calculating the dew-point have been based on the specific gravity of air, as determined by Delaroche and Berard, or ·267; the correct value is that obtained by Regnault, or ·237. With this correction, the discrepancies found to exist between calculation and observation are increased, and amount, on an average, to about 25 per cent. of the difference between wet bulb temperature and the dew-point. August and Apjohn erred in assuming that the air round the wet bulb falls to the temperature of the bulb, and becomes saturated. These two assumptions would jointly produce no error in the result if the depression of temperature in the different portions of air were exactly proportional to their increments of vapour tension, and if some of the air were saturated at the temperature of the wet bulb. But it is probable that when there is little or no wind, the mass of air which falls sensibly in temperature is larger than that which receives a sensible accession of vapour, and that in high wind the supposition that some of the air has fallen to the temperature of the wet bulb is more nearly fulfilled than the supposition that it has taken up enough vapour to saturate it. The effect of radiation, which is ignored in the formulæ, leads in the same direction as these two inequalities, and all three are roughly compensated for by attributing to air a greater specific heat than it actually has.

Ferrell, William. (*B.* 1871, 8.)

(*Page* 226.) Buchan attributes the low barometer in the Polar regions to the effect of vapour in the atmosphere; but the amount of vapour in the equatorial regions is far greater than in the cold Polar regions.

Frere, Sir Bartle. *Journ. Roy. Geog. Soc.*, vol. xl. (1871) (*rs*).

(*Page* 203.) In the Thurr droughts occur for months, and sometimes for years. Still, grasses thrive and spring up with amazing rapidity after the fall of a few inches of rain. The soil is loose, and the roots of the plants are of prodigious (*Page* 204) lengths. No animal requiring much water can stand its protracted droughts. Thus tigers are never seen in the desert, although they abound wherever jungle is to be found in these regions; leopards and lions are rare. Three (*Page* 205) foxes and a jackal are known. Wolves are numerous. The wild hog is absent. Of deer and antelopes, the only one is the gazelle, which is said to subsist without any moisture except that afforded by dew and herbage. Jerboas are the most characteristic animals. Snakes are numerous. There are horned cattle, sheep, and camels.

Hudson, Henry. *On Evaporation of Water.* *Symons's Meteorol. Mag.*, vol. vi., pp. 166-168 (*rsp*).

(*Page* 166.) The following propositions appear to embrace and explain the phenomena of evaporation observed by Mr. Dines :—

1. When air is saturated with moisture at temperature of atmosphere, neither evaporation nor condensation can take place. 2. When air is saturated, but the water of a higher temperature, evaporation must take place, for the air, which is warmed by contact with the water, being no longer saturated, is capable of receiving and carrying away additional moisture ; hence the water must lose weight, and also be cooled by the abstraction of the latent heat of the vapour thus eliminated. 3. When air is saturated, but the water of a lower temperature, condensation must take place on the surface of the water, for the air, chilled by contact, can no longer retain the same amount of vapour, consequently the weight of the water will be increased, and its temperature also must rise from the influence (*Page* 167) of the warmer air. 4. Let us suppose both the air and water to be several degrees above the temperature of the wet bulb, the air in contact with the water will obviously carry off vapour from it. Hence the weight of the water will diminish, and its temperature must fall, as in the case of the wet bulb, until the latent heat of the vapour so abstracted is exactly compensated for by the heat, from all sources, which the water-vessel receives. After this occurs, evaporation will still go on, and consequently the water will lose weight, although the temperature of the water may remain stationary. 5. Let us suppose the water to be several degrees below the dew-point temperature, while the air is several degrees above it ; the air now in contact with the water is capable of abstracting vapour until it reaches its temperature of saturation. But, being chilled further by the contact with the water, it is compelled, as I may say, to surrender its previous spoils again, so that when the water is a certain number of degrees below the dew-point, the weight of moisture which the air could vaporize, in falling to the temperature of the wet bulb, will be exactly balanced by the quantity of vapour which the colder water would abstract from the air after it had attained the condition of saturation ; so soon, however, as the temperature of the water rises above this point, although still, perhaps, some degrees below the dew-point, the evaporative influence will prevail, contrary to the first proposition laid down by Mr. Dines, that no evaporation takes place from water unless the temperature of the water is greater than that of the dew-point. At the close of the second table (p. 201) he gives an experiment totally opposed to such a conclusion. In the last line of his table, his dry bulb is at 59° and the wet bulb at 53·8° ; his calculated dew-point being 49·2°, and temperature of water 38·6°. After about a quarter of an hour, condensation ceased, temperature of water being 44°, and two minutes afterwards evaporation commenced, with water at 45°. He has not stated the temperatures of the wet and dry thermometers at these precise points, but I cannot believe that the dew-point had fallen, in the time specified, below 45° ; in fact, in the previous quarter of an hour the temperature of the dry bulb had risen from 58·1° to 59°, and of the wet bulb from 53·1° to 53·8° (his calculated dew-point having also risen). Now, assuming the temperatures of dry and wet bulb to remain at 59° and 53·8° respectively, my views lead to the following results :—I find the weight of water which 1000 cubic inches of dry air could vaporize in falling from 59° to 53·8° to be 0·35836 grains, and the maximum weight of 1000 cubic inches of vapour at 53·8° is 2·70631 grains. Hence, deducting the former from the latter, we have 2·34795 grains, which is the maximum weight of 1000 cubic inches of vapour at 49·69°, and this, by my calculation, is the dew-point, instead of 49·2°. Now, if we again deduct (*Page* 168) 0·35836 from 2·34795 grains (in order to find out at what temperature

below the dew-point the condensation of vapour is equal to the previous evaporation during the fall from 59° to 53·8°) we get 1·9859 grains, which is the maximum weight of vapour in 1000 cubic inches at 45°. Hence, according to my views, this is the temperature at which evaporation ought to begin to preponderate over the tendency to evaporation, and it is evident this agrees perfectly with what Mr. Dines has recorded as the result of his experiment. After this, in about eleven minutes, he states the temperature of the water to have risen to 49·8° and that 0·4 grains of water had been vaporized in the interval, so that after this amount of evaporation the water was probably very little, if at all, above the dew-point temperature.

Malet, H P. *Symons's Meteorol. Mag.*, vol. vi. (*rsp.*)

(*Page* 204.) In West India, at an elevation of 4,000 ft., I have frequently seen showers falling below me. I have walked into the clouds, and met first mist (*Page* 206), then drizzle, then rain. From numerous facts observed by me, I gathered that rain clouds vary in thickness from about a hundred yards to more than a mile, that the weight or size of the raindrops increases as they reach the point of attraction. This point is the earth, and may be a mountain top or a level plain; as the latter does not fall in with so much moisture as the hills, it gets less rain. Some seem to think that a cloud discharges its contents in actual raindrops; if it did, there would be no moisture to go on with. But it is otherwise, and while some of the vapour is accumulating into raindrops, the rest is passing on. In India there are seldom two layers or more of clouds; in England, as far as I have been able to ascertain, it never rains without two layers.

Monck, W H. S. (*B* 1871, 17.)

(*Page* 495.) Aqueous vapour is not so important an agent as is usually supposed. The specific heat of aqueous vapour at constant volume is ·313, and that at constant pressure is ·475, showing a ratio between the heat units expended on internal and external work of 1 to 0·517. In dry air the proportion is 1 to 0·421. In the one case, in round numbers, 30 per cent. is employed in producing expansion; and in the other 35 per cent. For equal quantities, the heat absorbed by vapour has little, if any, greater effect in producing air currents or barometric depressions than that absorbed by air.

Poey, A. (*B.* 1871, 18.)

[The new cloud is Dr. Clouston's pocky cloud. He noticed it in connection with the same meteorological conditions as are described by A. Buchan in 1868.]

Stewart, Balfour. (*B.* 1871, 20.)

(*Page* 63.) Charts of relative humidity are without value, and do not present the continuity shown in charts of vapour tension. Watery vapour is one of the most important elements in studying the movement of air. Charts representing the distribution of vapour of water would be of the greatest utility. The element of relative humidity is of little use in meteorological researches. Besides these two (*Page* 64) elements, there is what may be called the hygrometric quality, which is important. It means the weight of aqueous vapour per hundred parts by weight of air. As long as the pressure remains the same it will be represented by the vapour tension, and since the variations of pressure at the surface of the earth differ little, the hygrometric quality will be there approximately represented by the vapour tension. But under small pressure the vapour tension will not represent the hygrometric quality, which will then be indicated by the ratio between the pressure of aqueous vapour and that of air.

Stow, Rev. F. W. *Symons's Meteorol. Mag.*, vol. vi. (*rsp.*) (No. for June.)

(*Page* 70.) Does the old-fashioned hypothesis suggested for the decrease of rainfall with height account for the facts, especially the greater decrease in winter than in summer? Does it not assume what can be disproved—viz., that the temperature of falling rain is almost always below the dew-point of the air near the ground? And if it were true that the raindrops gain more than they lose till they reach the ground, would not the beginning of rain dry the air near the ground by depriving it of moisture, and even warm it by the latent heat given out in condensation? I am much more disposed to believe that, on the contrary, the drops lose volume by imparting moisture to the air, for it is a matter of common observation that when it begins to rain the air becomes damp and generally cold.

Symons's Meteorol. Mag., vol. vi. (*rsp.*)

(*Page* 144.) We give a *resumé* of Mr. Dines's observations on evaporation. A delicate balance was arranged with a vessel of water in one pan and weights in the other. It was found that evaporation from the hot water continued until its temperature fell below the dew-point temperature, as computed by Mr. Glaisher's tables, and that in cold water condensation ceased some 3° or 4° below the computed dew-point temperature. These results indicate one of three things: 1. That there is some error in the experiments. 2. That there is some error in the hygrometrical tables. 3. That the dry and wet bulb thermometers do not enable us to ascertain the dew-point correctly. The second phase of the investigation is given in the *Proc. Meteorol. Soc. for March*, 1871. Thus during some experiments it was found that when the difference of the dry and wet bulb thermometers amounted to 8° or 9° evaporation commenced from a surface of water at a time when the thermometer immersed in the water showed a temperature of from 3° to 4° below (*Page* 146) the temperature of the dew-point as obtained by calculation, but on repeating the experiment in air saturated with moisture, when the dew-point temperature could be obtained direct from the thermometer, the dew-point temperature and that of the water, when evaporation commenced, agreed with each other. As no satisfactory reasons have been assigned for this discrepancy, I made other experiments, as follows; small globes and cylinders, both of glass and metal, were used, the substance of which was made as thin as possible; these were filled with iced water; a thermometer, with a bulb 1½ inches in length, was inserted in the water, the stem of the thermometer passing through the centre of the stopper; the whole was then suspended from the beam of a delicate balance. The outsides of the vessels were, of course, immediately covered with condensation, the amount of which was only occasionally noted, the one object of the experiments being to determine the exact temperatures of the water at the time when condensation ceased upon the surface of the vessels, and the moisture deposited upon them commenced to evaporate; that time was clearly shown by the stationary position of the index rod attached to the balance, just previously to its commencing a retrograde movement. If the thermometer immersed in the water at the time this change took place fairly represented the temperature of the outside of the vessel, it would, without doubt, give also at the same time the true dew-point temperature. Every care was taken with the covering and supply of moisture to the wet bulb thermometers, and, as an additional precaution, two sets of dry and wet bulbs were used, the difference (8° to 9°) of which did not vary much from each other; but those which gave the widest readings, and, consequently, the lowest dew-points, were taken. Whether the vessels used were larger or smaller, of glass or of metal, or whether the moisture upon the outside was allowed to accumulate almost in drops, or the film of moisture so thin as to be scarcely weighable, the results were nearly

the same; condensation ceased, and evaporation commenced from the surface of the vessels at a time when the water inside the vessels was from 3° to 4° below the dew-point temperature, as obtained by calculation. It may be said the thermometer in the water does not give the temperature of the surface from which evaporation takes place; the objection has force; but it also applies to both Daniell's and Regnault's hygrometers as at present used. True, there are other differences in the mode of operation; in them it is a sinking temperature; in mine a rising one. In them the point of condensation is determined by the eye; in my experiments by a balance; but these differences do not seem to account for the different results. As the indications of the wet and dry bulb hygrometer had been found to accord with those given by Daniell's and Regnault's, I conclude that the factors given in Table I. of Glaisher's hygrometrical tables are incorrect. Now we come to the third phase of the inquiry—viz., a consideration of Dines's sensitive hygrometer, made by (*Page* 147) Casella. In it a stream of cold water passes through the vessel; at one end is a very thin black glass plate, beneath which is the bulb of a thermometer. The temperature of the upper and lower surfaces of the glass is nearly the same; and the slab does not differ from the thermometer bulb more than 2° or 3°. The glass is cooled by the water; as soon as dew appears on it the water flow is stopped, and the temperature is taken from the thermometers. This is the dew-point. By using a piece of wash leather to dry the glass successive deposits of dew may be rapidly obtained, when the dew-point will be found sometimes to vary considerably in a short time, the dew upon the glass appearing and disappearing several times in a minute. The instrument has extreme sensibility, and is perfectly under the control of the observer, and its price is very moderate.

1872.

Anderson, J. F. (*B.* 1872, 1.)

(*Page* 221.) He was able (at Pau) to see the small bodies alluded to by Waldner with the naked eye, or with a small telescope, by looking at the sky close to the sun's disc just within a shadow. On June 9th and 10th the haziness round the sun was produced by the reflection of the sunbeams from innumerable little particles. What were these particles? They certainly look like miniature snow storms.

Brumham, G. D. *Symons's Meteorol. Mag.*, vol. vii. (*rsp.*)

[No. for November.]

(*Page* 172.) Excessive moisture retards wheat. Hence the ripening of wheat depends (*Page* 173) on dryness of air as well as temperature. The early maturing of wheat indicates the previous prevalence of dry weather as much as, or more, than it does that of shade heat.

C., W. H. H. *Chemical Hygrometer.* *Symons's Meteorol. Mag.*, vol. vii. (*rsp.*)

(*Page* 155.) Air is drawn through U-shaped tubes containing chloride of calcium or strong sulphuric acid, by means of two turnover aspirators, each containing a gallon of air. The increase of weight in the chloride of calcium tube indicates the amount of moisture in so many gallons of air.

Davis, Henry. *Prestel's Hygrometer.* *Symons's Meteorol. Mag.*, vol. vii., p. 204 (*rsp*).

(*Page* 204.) There are objections to Prestel's hygrometer. Birds can drink from the open vessel; the wind would blow the water over the side in gales; and the atmospheric pressure would keep the water permanently in the gauge.

Haviland, Alfred. *Symons's Meteorol. Mag.*, vol. vii. (*rsp.*)

[No. for July.]

(*Page* 116.) In the western sky at Hampstead, on June 23rd, 1872, there were some persistent cirri, forming strange groups, which lasted for more than an hour. The cirri bristled (electrically ?).

Hudson, Henry. *Dew-point and other Hygrometers. Symons's Meteorol. Mag.*, vol. vii., pp. 19-20 (*rsp*).

(*Page* 19.) A limit to evaporation does not exist when the temperature of the air is higher than that of the liquid. I consider the dew-point in the case mentioned to be 49·69°, and that the air will take up vapour several degrees below, owing to (*Page* 20) its surplus heat. The amount of evaporation depends on so many circumstances, that in order to discover laws it will be necessary to separately investigate each circumstance.

Ingram, Hugh. *Symons's Meteorol. Mag.*, vol. vii. (*rsp.*)

(*Page* 229.) He calls mists vesicles of aqueous vapour (cloud proper). A raindrop, in displacing air as it falls, creates a vortex immediately behind it so as to suck in and attach to itself the particles of vapour nearest its path. Hence its increased size.

L., J. K. (*B.* 1872, 10.)

(*Page* 442.) Commander Maclear has noticed differences in the spectrum of different areas, and believes the changes in the atmospheric humidity distinctly correspond to the changes in the solar spectrum ; an increasing humidity manifests itself by a shortening of the blue, and by a well-marked development of aqueous bands in the red and yellow.

Miller, S. H. *Evaporation. Symons's Meteorol. Mag.*, vol. vii., pp. 111, 129 (*rsp*).

(*Page* 129.) What methods for measuring evaporation did Vivian, Lamont, and Prestel suggest ?

Rieder. (*B.* 1872, 17.)

(*Page* 39.) At Engelberg, November 14th, 1868, 5 to 6 A.M., repeated flashes of lightning. Shortly before five a swiftly passing flash was observed, while the sky was completely overcast.

Spottiswoode, William. (*B.* 1872, 23.)

(*Page* 334.) The diffusion of light in the air depends upon the presence of aqueous particles. That scattered by coarse particles is white, that by fine blue.

Stow, Rev. F. W. *Symons's Meteorol. Mag.*, vol. vii. (*rsp.*)

[No. for December.]

(*Page* 197.) In moist weather there is little sun, in dry there is much. Perhaps the influence of such weather on wheat is due to variation of sunshine, not of moisture. In the inland districts of Yorkshire the temperature rises faster in the morning than on the coast, owing to the comparative absence of mists, etc.

Waldner, H. (*B.* 1872, 25.)

(*Page* 304.) On looking through his large telescope at Weinheim, he caught sight of a number of luminous little bodies passing rapidly towards the east, which the focal distance of his lens showed were at from 200 to 4,000 metres only from the earth ; the most numerous swarm occurred at about 500 metres. Their diameter varied from 10 to 52 mm., the average being 32 mm. The shape varied ; the greater number were oblong, angular, resembling flakes ; some few were orbicular, while some were

stellate. On certain days, especially in April and May, they passed by without interruption for hours. Their number was connected with the purity of the sky. The daily minimum occurred in the morning and evening, and the maximum at noon. The annual minima were in summer and winter, and the maxima chiefly from April 20th to May 15th, and a lower one in August and September. Their number often increased after clouds had passed. Their velocity was irregular in the lower strata, being about two metres in a second, but became more regular in the higher strata, where, at 3,000 metres, I found them to pass eight metres during the same period, a rapidity agreeing closely with the cirri, which often passed at or above (*Page* 305) this distance. They all glittered in sunlight. In the lower strata they changed their direction every moment, or fell, but slower than gravitation requires. Their direction of movement corresponded nearly always with the wind and cloud movements. These bodies are evidently snowflakes and ice crystals. The minimum during winter may be owing in part to the deficiency of light.

Whipple, J. M. *Chemical Hygrometer. Symons's Meteorol. Mag.*, vol. vii., pp. 199-200 (*rsp*).

(*Page* 199.) The chemical hygrometer, described by W. H. H. C. is not of much use to the meteorologist, as it requires much patience and manipulative skill. It is a very laborious method of observing, and, after all, it only gives a mean (*Page* 200) for the time during which the observation is made. I think eventually we shall have to resort to some such form as Whitehouse's.

Nature. (*B.* 1872, 28.)

(*Page* 118.) There is much misconception as to the mode in which forests increase the amount of moisture in the air. They do so chiefly by pumping up the superfluous moisture from the soil and exhaling it from the leaves. Pettenkofer (Sitz. Akad. München, 1870. Bd. I., Heft 1) found that in an oak tree evaporation increased from May to July and then decreased till October. The total amount of its evaporation in the air was 539·16 centimetres of water. The average rainfall of the same area would be 65 centimetres, so that this evaporation is 8½ times more than that of its rainfall. This excess is drawn up from a great depth, so that the trees restore to the air what would otherwise go to the sea.

Symons's Meteorol. Mag., vol. vi. (*rsp.*)

(*Page* 213.) Describes Daniell's hygrometer. It was described by Daniell in 1820 (*Page* 214), and at the time was by far the best measurer of atmospheric moisture. Its accuracy has subsequently been overrated. Owing to the necessarily small size of the enclosed thermometer it is impossible to read accurately small fractions of a degree; and it is open to question if the thermometer indicates the actual temperature of the outer glass surface.

Vol. vii. (*rsp.*)

[No. for May.]

(*Page* 63.) Sawyer, in his 'Climate of Brighton,' has some weather proverbs, such as—

'When Wolsonbury has a cap
Hurstpierpoint will have a drap.'

This is a south country modification of a common prognostic, such as the following, some of which are taken from Inwards' 'Weather Lore.'

'If Riving Pike do wear a hood,
Be sure the day will ne'er be good.'

'When Cheviot ye see put on his cap,
Of rain ye'll have a wee bit drap.'

'If Roesberry Topping wear a cap,
Let Cleveland then beware a clap.'

'When Breddon Hill puts on his hat,
Ye men of the vale beware of that.'

'When Largo Law puts on his hat,
Let Kellie Law beware of that;
When Kellie Law gets on his cap,
Largo Law may laugh at that.'

Largo Law is to the S.W. of Kellie Law.

[No. for June.]

(*Page* 73.) Dr. Ballot enforces the desirability of more frequent observations of the height of clouds.

[No. for August.]

(*Page* 129.) The following description of Prestel's apparatus is from *Procs. Meteorol. Soc.*, vol. iii., pp. 338-339. It comprises an open vessel of water. (*Page* 130) Connected with it is a measuring tube with a scale. The tube is filled with water and placed inverted in the vessel. As the water from the large vessel evaporates it is supplied from the tube. The open end of the tube has a brass ring mounting with a semicircular hole in the side through which the tube communicates with the vessel.

[No. for October.]

(*Page* 161.) M. Lemoine, in a paper read to the British Association, refers to Mr. Chapman's observations in South Africa. The desiccation of the country has been going on since the draining off of the waters owing to evaporation. The destruction of herbage and grass by fire, the use of the axe by native and colonist, and the formation of sheep walks, had facilitated the process of evaporation. As an illustration of the effects of evaporation producing desiccation, he quoted an experiment made by William Blore, at Wynberg Hill, about eight miles from Cape Town. He sank two cylindrical jars of the same size to the depth of 4 in., leaving them projecting an inch above the surface, and covering each with gauze to prevent ingress of sand, etc., and flies. The one was sunk where it was partially protected, but not covered by bush; the other was sunk in a newly-cleared plot of ground measuring about 60 ft. in diameter, surrounded by sugar bushes (*Protea mellifera, Thunb.*), of a considerable height, and otherwise protected from the prevailing wind by a belt of pine trees, about 120 ft. distant. Into each of these jars was put 20 ozs. of water on January 31st, at 10 A.M. On February 5th, at 5 P.M., the water remaining in each was carefully measured. The evaporation from the jar sunk in the cleared ground had been more than double the evaporation from that which was partially protected, though not covered, by the bush; the former being 1·854 in.; the latter ·863 in. The same results were obtained on repeating the experiment. Mr. Blore remarked that had the experiment been made in a more arid district the evaporation would have been greater; and that had it been made in the open country the difference would have been more marked. But taking the results obtained, the conclusions he arrived at were as follows:—The excess of evaporation from the more exposed above that from the more shaded jar was 1 in., or more accurately, ·991. An inch in six days will give for 102 days (the ordinary duration of the hot windy and dry season in the district) 17 in. This is equal to about 384,000 gallons per acre, and supposing 1,000 acres to be burned, blackened, and dried, what with sunlight, fire, heat, and wind, the evaporation would be an excess of 384,000 gallons of water above what would have been evaporated if the bush or grass had been unburned. Mr. Blore ascertained by experiment that on Wynberg Hill, while the deposit of dew upon a green surface amounted to 4·75, that on a white surface amounted only

to 2, showing that the deposit of dew upon a green surface is more than double that upon a white; and he further ascertained that while the difference of temperature in the water in the two jars employed in the former experiment was only a few degrees the difference of temperature between black ground and ground shaded by bush was 25°, which would occasion a vastly greater difference in the amount of evaporation than that which occurred in his experiment. Humidity of air is of more importance than rainfall, and it is not necessary, in order to account for the phenomena observed, to suppose that forests attract clouds, neither is it necessary to suppose that they increase the rainfall otherwise than they do by the precipitation of the same moisture in the form of rain. The moisture of the humid atmosphere charged with carbonic acid and ammonia, attracted by the soil, does more to promote vegetation than would the same quantity of moisture falling in rain or applied by irrigation.

[No. for November.]

(*Page* 180.) George Dines described a new hygrometer. Objections had been made to the use of glass, owing to its non-conducting qualities, and in this form he used both glass and highly polished gilt metal. The metal was found to have no advantage over glass. [See Notes, 1823, Daniell, p. 142.]

1873.

Barns, J. W. *Journ. Roy. Geog. Soc.*, vol. xlii. (1873) (*rs*).

(*Page* 405.) The date palm characterizes arid climates with extreme summer heat and a low winter temperature.

Blakiston, T. *Journ. Roy. Geog. Soc.*, vol. xlii. (1873) (*rs*).

(*Page* 140.) At Hakodadi, fog is confined to the spring and summer months, but principally June.

Brine, Lindesay. *Journ. Roy. Geog. Soc.*, vol. xlii. (1873) (*rs*).

(*Page* 361.) In crossing the high lands of Guatemala, it is observable that the Indians dwelling among the mountains are much darker than those in the plains, and indeed it may be laid down as a general law that throughout Central America the colour of the native varies according to the height above the sea, and in a manner entirely opposed to what would naturally be expected. The skin of those who dwell in the highest and coldest regions is almost black, while below in the warm valleys and near the coast it is of a pale copper colour.

Grant, J. A. *Journ. Roy. Geog. Soc.*, vol. xlii. (1873) (*rs*).

(*Page* 259.) While delayed at Karagweh, I was much struck by the extreme blackness of skin in a race who came there from the Lake Victoria direction to sell coffee. The blackness of their skins reminded me forcibly of the races dwelling in the swampy regions of the Terais of India, and this to me at once marked their origin as a race living among swamps or lakes. They were Wahia, who live on the shore of Victoria Lake. Their spear is made of a white knotty wood, not of bamboo, for bamboo is not indigenous to swampy countries; it chooses rather to grow away from water.

Maury, T. B. (*B.* 1873, 7.)

(*Page* 125.) When once an area of low barometer is formed, it is the nucleus for a vast aggregation of meteoric forces. No matter how small at first, under favourable atmospheric conditions, the *courant ascendant* is formed, condensation aloft sets in, and the precipitation only seems to add fuel to the flame of the cyclonic engine. This process widens in geographical area, and after a few hours have elapsed, the storm may so develop as to cover a continent with its portentous canopy of cloud,

while simultaneously strewing an ocean with wrecks, and throwing out in the open sky, more than a thousand miles in front, the fine filaments of the premonitory cirrus and cirronus. The depression in a cyclone is maintained so long only as the centre moves in a region sufficiently supplied with aqueous vapour to feed it. It is physically impossible for a storm to maintain its course or force over a dry and (*Page* 147) desiccated surface. The southerly winds of the north hemisphere come from the equatorial regions, and are highly charged with aqueous vapour. This vapour is absolutely essential to the sustenance of storms. The storm vortex is on the side where the greatest quantity of vapour is found. While yet in the band of easterly trade winds, the storm will invariably work its way to the most humid regions unless mechanically borne away by the great aerial current in which it is embedded. The cyclone tracks over all the oceans lie in the central bands of the great ocean currents of high temperature and great evaporation.

Mott, A. J. (*B.* 1873, 8.)

(*Page* 161.) The amount of evaporation must be the chief element in the question of rainfall; and the total evaporation must depend on the amount of wind; and thus be increased in proportion to the speed of the wind and by the increased surface caused in storms when waves and foam are created. The evaporation during a cyclone must be enormous. Wind is almost always drying even when rain is falling. The solar spots probably cause inequalities of temperature, which by the formation of barometric differences will give rise to special areas of evaporation.

Stevenson, T. (*B.* 1873, 15.)

(*Page* 153.) Hygrometric gradients should be used, and there should be horizontal and vertical hygrometric sections of the air made by a series of instruments near together.

Nature. (*B.* 1873, 17.)

(*Page* 342.) The dry and wet bulb is not trustworthy at low temperatures, and in cases of extreme dryness. No hygrometer yet devised gives approximately exact results in all cases. The instruments for measuring the rate of evaporation are the least satisfactory of those used in meteorology. The data are important elements.

Symons's Meteorol. Mag., vol. viii., p. 36 (*rsp*).

[No. for April.]

(*Page* 36.) At the Leipzig Conference Question 7 was :—What apparatus should be employed for determining the hygrometric condition of the air? Are the wet and dry bulb thermometers sufficient? Can the hair hygrometer be employed, and under what restrictions?

The answers were as follows :—Sr. F. da Silveira : Psychrometer for continuous observations. The hair hygrometer can never be accurate when exposed to the atmosphere. Carl Fritsch : Psychrometer sufficient and preferable to hair hygrometer. Thinks observers are not sufficiently careful to see that the wet bulb is really wet. Carl Hoffmeyer : Knows of nothing better than dry and wet bulb. Dr. Mohn : Psychrometer is most convenient, but for low temperatures hair hygrometer must be used with it. Professor Ragona : Strongly recommends a psychrometer by Tecnomasio Italiano in Milan. Calls attention to observations by Belli and Cantoni, showing that the results of thermometers with spherical bulb, covered with linen and moistened by a wetted wick, are unreliable. Believes hair hygrometer to be trustworthy if originally set by a psychrometer; recommends it to be enclosed in wire gauze. Symons : Dry and wet bulb not perfect, but preferable to Saussure's hair hygrometer. Dr. Wolf : Psychrometers always wrong when frost and

thaw alternate rapidly; hair hygrometer should, therefore, be used as a check. The Committee: Psychrometers faulty in cases of extreme dryness; the hair hygrometer is erroneous at the dew-point. Neumayer: Regnault's hygrometer with an aspirator should be used. Von Oettingen: Regnault's hygrometer sometimes fails at very low temperatures.

[No. for May.]

(*Page* 53.) Question 15 was:—What apparatus is to be recommended for the measurement of evaporation? What is the most suitable exposure for the evaporimeter?

Answers:—

(*Page* 54.) Sr. F. da Silveira: Should be exposed to rain, sun, etc. Carl Fritsch: A vessel similar to a rain gauge, but shallower, exposed to sun and rain, but guarded against undue heating. Capt. Hoffmeyer: Attention must be paid to the temperature of the vaporimeter. Professor Ragona: Recommends Tecnomasio Italiano's vaporimeter or his own self-recording one. Bordeaux Meeting: Piche's hygrometer gives the most favourable results. Prestel: Recommends his own vaporimeter. Ebermayer: Recommends Lamont's vaporimeter.

Question 16:—In what way should the proportion of cloud in the sky be estimated and indicated? Is it desirable to introduce a special and universal language for clouds?

Answers:—

Sr. F. la Silveira: Clear sky=10; overcast=0. The introduction of universal symbols very desirable. Carl Fritsch: During the prevalence of thin cirrus and the breaking up of ground fog, there is difficulty in determining the true amount of cloud. The introduction of general symbols desirable. Dr. Mohn: Blue sky=0; overcast=10. Symbols very convenient. Symons: Have symbols if possible. The Bordeaux Meeting: The adoption of tenths of clear or cloudy sky will involve the disadvantages of two figures for telegraphy, instead of one. Approve use of symbols. The Committee recommend 0=clear sky; 10=overcast; that symbols be used; and that a selection be made from those submitted to next Congress.

(*Page* 95.) Ragona notices that at Modena the minimum is below 20 nine months out of the twelve. The lowest observed was 7 on April 9th, 1867.

1874.

Burder, G. F. *Symons's Meteorol. Mag.*, vol. ix. (*rsp.*)

[No. for September.]

(*Page* 123.) According to my own observations the inverted cumulus or pocky cloud never occurs in a marked degree except in the neighbourhood of a thunderstorm.

Elias, Ney. *Journ. Roy. Geog. Soc.*, vol. xliii. (1874) (*rs*).

(*Page* 143.) From September 24th to November 2nd, on which last date he was near Uliassutai in Mongolia, the day almost invariably broke clear and still, and remained so until nearly noon, when a strong north-wester would spring up, and with a more or less clouded sky, continue to blow until about an hour after sunset when it would die out, and the clouds would roll away.

Kirkwood, J. P. *Symons's Meteorol. Mag.*, vol. viii. (*rsp.*)

(*Page* 196.) Give me titles of books relating to evaporation.

Markham, C. R. *Journ. Roy. Geog. Soc.*, vol. xliii. (1874) (*rs*).

(*Page* 95.) The great heat of the Polar regions and the excessive cold are due to the dryness of the air allowing of radiation from the sun and from the earth.

Ryves, Rev. J. T. *Symons's Meteorol. Mag.*, vol. ix. (*rsp.*)

[No. for August.]

(*Page* 103.) At Buildwas, on July 19th, the dry bulb read, between 3 and 4 P.M., 87°, the wet bulb 26°, which indicates a relative humidity of about 24.

Stow, Rev. F. W. *Symons's Meteorol. Mag.*, vol. ix. (*rsp.*)

[No. for September.]

(*Page* 115.) The absorption of the direct solar rays by the vapour of the atmosphere is proved in several distinct ways. 1. It is found that the elastic force of vapour is less on the ten days in each month in which radiation is most powerful, than on an average of the whole month. This is proved by five years' daily observation at Strathfield Turgiss, 1869—74; two years at Hawsker, near Whitby (1869—71); and one year's observation in 1872 at Harpenden. 2. It was also found by the above observations that N. and N.W. winds, which contain little moisture, are very favourable to solar radiation; whereas S. and S.E. winds are usually accompanied by much less powerful sunshine. The N.E. winds of spring, which are excessively dry, are also accompanied by intensely powerful solar radiation. 3. By frequent observations during cloudless weather, with nearly constant vapour tension, curves are obtained, representing the daily variations in solar radiation, produced by the changes in the sun's altitude, and consequent alteration of the length of the path which the beams pursue through the atmosphere. From these the percentage of the heat rays, which would be absorbed by the atmosphere if the sun was vertical, can be approximately determined, assuming that the tension of vapour remained as it was on the day or days of observation. It is then possible to calculate the amount of radiation due to the altitude of the sun at noon in the middle of each month for a constant vapour tension, and to compare this with the amount actually observed in each month on cloudless days. In this way it is found, that when the tension of vapour falls below the amount on the day which furnishes the data for calculation, the radiation rises above the calculated amount, and *vice versâ*. In fact, the sun's rays are more intense in winter than in summer, when the difference of altitude at noon is allowed for, because the absolute amount of vapour in winter is so much less. About 10 or 12 per cent. is the minimum of absorption of the sun's heat rays, while the maximum equals or even exceeds 20 per cent. Solar radiation increases with elevation above sea-level. Between 470 and 1,800 feet the difference is 5 per cent. of the amount observed at the lower station when the sun's altitude was 20°, and above 3 per cent. when it was 26°.

Strahan, W. *Symons's Meteorol. Mag.*, vol. ix. (*rsp.*)

[No. for August.]

(*Page* 112.) The following are cases of extreme dryness observed in India :—

		DRY.	WET.	DIFFERENCE.
June 4th, 1869.	Gwalior . . .	110·3°	69·7°	46·6°
,, 19th, 1873.	Meean Meer . .	112·2°	70·2°	42·0°

Thomson, J. *Journ. Roy. Geog. Soc.*, vol. xliii. (1874) (*rs*).

(*Page* 104.) In South Formosa the wet season begins in May and ends about September [and hence the dry season would be from September to May. The lat. is about 23° N.].

Wilson, W. *Journ. Roy. Geog. Soc.*, vol. xliii. (1874) (*rs*).

(*Page* 211.) In Palestine the dews are so heavy that they penetrate the tent and wet everything in it. The rainy season commences at the end of October or beginning of November, and lasts till March [so that the dry season would be between March and October].

Symons's Meteorol. Mag., vol. viii. (*rsp.*)

(*Page* 196.) Many titles of books on evaporation are given in 'British Rainfall,' 1867 to 1872. [He gives nine others, which are entered in 'Bibliography.']

Symons's Meteorol. Mag., vol. ix. (*rsp.*)

[No. for December.]

(*Page* 171.) Professor Ragona, in his 'Lettere Meteorologiche,' treats of the increase of humidity and the decrease of temperature which produce rain. He finds that when it rains at Modena the average humidity is 87·8. In England the mean value would be nearer 97·8.

1875.*

Abercromby, Hon. R.

(*Page* 274.) The heat and damp which accompany cyclones are phenomena which (*Page* 275) are never absent in any part of the world. The character and quality of this heat differ greatly from that due to radiation. Extreme damp, mugginess, and a peculiar feeling of oppression are the leading features. As to the source of this heat and damp, it is evident that since their position relatively to the cyclone centre is always the same, they must be due to some phenomenon of cyclonic motion, and their isolated position shows that they are not merely due to the setting in of a (*Page* 276) southerly wind. There is strong presumptive evidence that the heat and damp which accompany one portion of a cyclone are due to a compression of that portion. Behind the centre of a cyclone is an area, less defined than the heat area, but possessed of opposite qualities, viz., cold, dryness, and an exhilarating influence on man and animals. This is probably due to rarefaction.

Blanford, H. F.

(*Page* 189.) The effect of increased radiation [solar] must be to increase evaporation, and, therefore, the clouds.

Smyth, P.

(*Page* 232.) He refers to the very heavy rains of July 1875 in France and England notwithstanding the barometer was high and steady. When in London on July 14th to 16th, he saw the line D with the spectroscope dark and broad. When he left the weather cleared up, and at York, where it was fine, the line was sharp, but narrow. In Edinburgh, on July 17th, the line was again seen very broad during bright (*Page* 253) sunshine, and was followed a few hours after by a steady rain. On July 20th there was a sensible alteration of the abnormal spectrum band. On July 23rd it rained with a normal sky spectrum, but then the barometer was low, wind W., and the temperature had fallen.

Nature.

(*Page* 100.) Hon. R. Abercromby (Meteorol. Soc., June 19th, 1875) remarked that a light ascensional column would give rise simply to an overcast sky, and a (*Page* 244) stronger one to rain. Scott described Lowe's graphic hygrometer. On the relation of temperature and moisture in the lower strata of the atmosphere at daybreak, R. Rubenson, in *Kong. Vetensk. Akad. Forhandl.*, Stockholm, January 13th, 1875.

Nature.

(*Page* 79.) Meteorol. Soc., November 17th. On a self-regulating atmometer. H. Miller.

* For fuller references, titles, and bibliographical details, referring to 1875 and subsequent years, see the Bibliography near the end of this volume.

(*Page* 399.) Inst. Civil Engineers, February 29th. On evaporation and percolation. C. Greaves.

1876.

Murphy, J. J.

(*Page* 6.) If we are drying up, it must arise either from diminished ocean surface, or less heat, both of which would decrease evaporation. There seems to be no evidence in support of either, so that the diminution of rainfall must be a local phenomenon.

Murray, D.

(*Page* 76.) Sir C. W. Thomson, at the British Association, states that the reason why the water is moving in a body from the South Sea is that there is a greater amount of evaporation in the North Atlantic and over the north hemisphere generally, than there is of precipitation ; whereas it seems almost obvious that in the south hemisphere, in the huge band of low barometric pressure round the south pole the precipitation is in excess of evaporation. He suggests that certain points should be cleared up before this is admitted. Is there no compensating current from the north ? Is it likely that the evaporation in the north hemisphere is greater than that in the south ? Even supposing this is so, is it known that this vapour is carried into the Antarctic regions for pre- (*Page* 77) cipitation ? The wind phenomena militate against the view that a large body of vapour is carried from the north to the south hemisphere.

Nature.

(*Page* 520.) Moisture is, next to temperature, the most important climatic characteristic of wind. The humidity of winds having the same direction varies according as it belongs to a cyclonic or anticyclonic area.

Nature.

(*Page* 161.) *Zeits. f. Meteorol.*, March 1st. On the relations of temperature and moisture in the lowest atmospheric strata during the formation of dew, by R. Rubenson, Dr. Hamberg concluded that in the lower strata temperature (*Page* 162) increases with height on frosty nights, and that the absolute moisture is less on the ground than a few feet above it. Dr. Rubenson obtained some results in the summer of 1871. Before the fall of dew the absolute moisture continues to increase, and is greatest on the ground, diminishing with the height. As soon as dew begins to fall, moisture decreases on the surface of the ground, and the decrease keeps pace with the decrease of temperature. The decrease of moisture extends upwards rather rapidly, and can be detected at 4 feet just after the first deposition of dew. On the ground, the decrease per hour amounts to a maximum of about ·73 mm. ; while half a foot above it the decrease only reaches ·65 mm., which is less than what corresponds to the lowering of temperature. The higher the instrument the later does the decrease of moisture show itself, and the less the change per hour. It appears that owing to a fall of temperature on the ground the air immediately above it becomes saturated, dew falls, and temperature and moisture diminish. At a certain point, owing either to diffusion or a descending current, fresh vapour supplies the place of that condensed as dew, and part of the loss of each stratum is made up by the moister strata above ; but not the whole, for the diminution continues in all the strata. Time being required for the propagation of the

decrease upward, the lowest stratum loses more of its moisture than any of the strata above it.

Nature.

(*Page* 444.) (Acad. Sci., Paris, August 28th.) Fautrat, in testing the influence of pine forests on the humidity of the air, found that the annual difference in saturation was in favour of the air above the pines ten hundredths.

(*Page* 562.) (Bull, Acad. Roy., Belgique). Montigny says scintillation increases with increase of vapour tension. It increases with the arrival of moist weather at all seasons.

Nature.

(*Page* 527.) D. Whitney has an article entitled 'Are we drying up?' in the *American Naturalist* for September 1876. It refers to the evidence of the former existence of larger and more extensive lakes in areas which are now without them, and also of diminished lakes and rivers. The drying up may possibly be owing to changes in the obliquity of the ecliptic, or in the perihelion distance of the earth.

Symons's Meteorol. Mag., vol. xi. (*rsp.*)

[No. for December.]

(*Page* 154.) [A description is given of the hygrometers and evaporimeters exhibited at the Loan Collection at the South Kensington Museum. Only those details are given here which bear upon aqueous vapour as an element of climate, or which may elucidate the history of investigation.] An old hygrometer was shown, designed by John Coventry. It consists of a number of discs of paper strung on a wire, and attached to the short arm of a lever; the long arm travels over a scale. The paper was probably saturated with salt, and its weight varied with the humidity of the air. Klinkerfues's bifilar hygrometer shows the humidity and the dew-point by inspection. The reduction is effected by means of two discs, one outer and one inner. There is an old dew-point instrument which we believe belongs to the Royal Society. It is an ordinary thermometer with a black bulb. The bulb is surrounded by muslin, and cooled by means of ether. The dew-point temperature is read off when dew appears on the black glass. It is the oldest of its class, but has no name attached to (*Page* 156) it, and no record of its history is given. Dr. Geisler's form seems to have great merits. A large bulb terminating the thermometer has muslin over it, and is cooled by ether. This bulb is connected by a tube with the large bulb of the thermometer. In this latter bulb is a hermetically-closed vessel containing ether. The cooling of the terminal bulb causes the ether of the interior of the thermometer to evaporate. And the thermometer bulb is cooled until dew appears, when the temperature gives the dew-point temperature. The evaporation measurers are not reliable. Lamont's atmometer has the defect that the small quantity of water is liable to be unduly heated. Professor Osnaghi shows the steel-yard evaporimeter. A vessel is at one end 5 in. in diameter; it contains water. As evaporation proceeds an index traverses a scale. The water is liable to undue heating, owing to its small bulk. In Ebermayer's evaporation apparatus (*Page* 158) is a box filled with soil, kept constantly moist by means of a reservoir. The objections to it are that 5 inches of soil is not the same as so much soil *in situ*, as the latter can draw upon the soil beneath; and the whole apparatus is apt to become abnormally hot. Morgenstein's atmometer is based upon the principles of capillarity and of Mariotte's bottle. Sand is saturated with water by capillarity supplied from a burette closed from the air on its upper end. A

tube runs from the sand into the burette, and supplies air to the latter as the water evaporates from the sand. When the burette is nearly filled with air it is apt to be affected by temperature. This defect is remedied by means of a globular vessel, which receives any water that may be forced out in this way. The evaporating vessel is embedded in some badly conducting material. Its area is one square decimetre (4½ in.). The instrument is sensitive to the fraction of a drop of water. It may give accurately the loss from a surface of saturated sand, but it is quite unsuited for exposure to sun and rain. Prestel's atmometer (*Page* 159) was the earliest in which the bird fountain principle in Mariotte's bottle was applied ; Morgenstein's is a refined edition of it.

1877.

Bonavia, E.

(*Page* 101.) He refers to the collection and increase of clouds early in October 1877, at Lucknow, before 3 P.M., and their gradual complete dissolution by two hours after sunset, as an indication that the cloud region became decidedly warmer after sunset than it had been during the day.

Broun, J. A.

(*Page* 333.) It appears that the monsoons on the west coast of India have a central current of maximum vapour depth or of velocity, which he suggests may be shifted north from year to year, according to some law like that of sun spots. [The principle is of general application to other areas.]

C., H.

(*Page* 43.) For years we [in Newfoundland] have marked an intimate connection between the colours of clouds and the weather. Thus we have the cold dark blue and grey and the reddish-yellow masses of clouds as indicative of cold and snow, and we have the light bright grey with bright edges as indicating or accompanying a hard frost ; the inky cloud flying in shreds, as indicative of wind and rain ; the mottled cloud of the same colour or thereabouts is the sure indication of rain ; the sickly-looking green, the deep blue gloom, the muddy, angry-looking red, and other such tints, as forecasts of storm, snow, rain, etc. ; and frequently before a north-easter we have the grey-bluish and whitish clouds setting from N.E.

Czerny, F.

(*Page* 239.) It is purely the winds which determine the condition of moisture of the (*Page* 240) atmosphere. If an equatorial current was to rise over a high mountain range, it may appear on the other side as a hot, withering wind, the *föhn* of Continental writers, in the thirsty regions. [See Notes, 1861, Eaton, p. 13.]

Hill, S. A.

(*Page* 506.) It may be said that the fact that the rainfall is greatest in maximum sun-spot years, argues increased evaporation during these years. The great majority of the rainfall stations examined are within or near the tropics, or in the maritime districts of temperate regions, and their more abundant rainfall in years of maximum sun-spots might be explained by the diminished carrying power of the winds at that epoch of the Solar cycle.

Ley, Rev. W. C.

Page 254.) Local depressions starting from the edges of the great areas of excessive evaporation seem to be governed in their course by the distribution of

relative humidity, and to be determined towards those districts in which precipitation is most in excess of evaporation. Consequently their forward development is generally somewhat towards the poles. In the south hemisphere the middle latitudes are almost entirely occupied by surfaces in which evaporation is excessive. In the northern they are represented, to a large extent, by areas of relatively slight (*Page* 334) evaporation. The easterly winds felt on the south border of a small cyclone, if pursued for a very limited distance, are often found to have undergone a complete change in the aspect of the clouds which they carry and in their humidity.

Ley, Rev. W. C. *Symons's Meteorol. Mag.*, vol. xii. (*rsp.*)

[No. for February.]

(*Page* 9.) *Picus viridis.* Its laughing cry is seldom heard during humid weather, or when the sky is much overcast. The greenfinch is especially noisy in sultry, overcast weather.

Nature.

(*Page* 210.) Contributions to hygrometry. The wet bulb thermometer. By W. Marriott, read to the Meteorol. Soc., December 20th, 1876. The observations were made to determine what a wet bulb should be. Ten thermometers were used as wet bulbs. With three bulbs the water receptacles were placed at different angles, but it was found that the readings were not affected by the position of the water receptacle. Others were used with different thicknesses of muslin and conducting threads; the thermometers with the thinnest muslins always gave the lowest readings. Three pairs of dry and wet bulbs were used, one with a closed water reservoir, 6 in. from the dry bulb; the other two having open reservoirs which were respectively 3 in. and 1 in. from the dry bulb. It was found that the dry bulbs of the two latter read lower than the former in fine, dry weather, but when the air was damp, and during rain, they generally read higher. The wet bulbs of the latter read a little higher than the former; this was mostly the case in damp weather.

Hon. R. Abercromby, Visibility, read to Meteorol. Soc., December 20th, 1876. Visibility is a very trustworthy prognostic of rain. The usual explanation that much moisture increases the transparency of the atmosphere is not borne out by (*Page* 541) observation. A correspondent in *Journ. Soc. Arts*, notices that in Ceylon, where the air is damp, the fruit of the coffee-plant has to be picked at maturity, else it would mould on the tree; whereas in Arabia, where the climate is dry, the fruit is allowed to ripen and drop off.

Nature.

(*Page* 197.) Steppes are characterized by absence of wood, the sandy surface is covered with grasses, dwarf herbs, and stunted bushes, which increase rapidly after the rainy season, but fade away altogether in the dry season. The steppe is defective in having no regular supply of water, being only here and there covered by streams, marshes, and lakes. The fauna of the steppe is characteristic, and is never met with in woody or marshy places. The most remarkable are the steppe rodents, such as jerboas, sousliks, and voles.

(*Page* 295.) (Hoffmeyer, in *Naturen*, June 1877.) Dr. Hann several years since explained the physical properties of the *föhn* wind. The air is forced over the mountains; in ascending it expands, and becomes cooled. On descending again it is compressed and heated. Its temperature rises more and more above the dew-point, and moisture will, with continually increasing ease, be held dissolved in the state of vapour. [See Notes, 1877, Czerny p. 240.]

(*Page* 336.) (Acad. .Sci., Paris, August 6th.) Comparative influence of leafy woods and resinous woods on rain and the hygrometric state of the air, by M. Fautrat. If vapours dissolved in the air were apparent like fogs we should find forests enveloped by a large moist screen, and for pine forests the envelope would be greater than for others. Pines retain in their branches more than half of the water poured on them, while leafy trees let 58 per cent. go to the ground.

(*Page* 369.) (Dr. Hamberg.) The absolute humidity of the air on clear nights in which no dew is deposited decreases from the ground upwards, just as happens during the day ; but, on the other hand, with dew the humidity is least nearest the ground and increases with the height, and this influence of dew in diminishing the humidity extends upwards to at least 22 feet. Since his observations clearly show that the absolute humidity begins in the evening to diminish near the ground before any dew is observed to be deposited, and also diminishes at all heights on those nights during which no dew whatever is formed, Dr. Hamberg is of opinion that the diminution of the humidity is to be sought for in other physical causes than the deposition of dew.

(*Page* 392.) (Acad. Sci., Paris, August 20th.) Faye : The phenomena relative to the exceptional winter of 1876—7 are attributed by Hebert to a succession of strokes of sirocco which have communicated the heat and drought characteristic of them. The sirocco stroke, which caused the very mild dry weather in the beginning of the year, belonged to three great cyclones, which came, like all the others, from the Atlantic. [Perhaps this refers to Paris.]

Nature.

(*Page* 134.) (Hon. R. Abercromby. Meteorol. Soc., November 21st.) In a cyclone the broadest feature of the weather is an area of rain about the centre surrounded by a ring of cloud, beyond which the sky is clear. The position and precise forms of these areas vary with the type of pressure distribution, with the intensity of the cyclone, and with the rate of its progress ; they are also influenced by local, diurnal, and seasonal variations. By recording the appearance (*Page* 135) to a single observer of any part of a cyclone as it passes over him, it is discovered that the area of rain and cloud ring may be divided into two portions,—the front and the rear,—differing in physical appearance and general character of the weather by a line drawn through the centre, in front of which the barometer is falling and in rear of which it is rising. In anti-cyclones synoptic charts show great irregularity in the positions of clouds, etc.

(*Page* 156.) (Fautrat. Acad. Sci. Paris, December 10th.) Above pines in the daytime there is always a rise of temperature from the solar heat being retained by the vapour enveloping the tree tops.

1878.

Abercromby, Hon. R.

(*Page* 143.) The process of averaging has resulted in the discovery of diurnal (*Page* 145) and annual variations of vapour and humidity. A watery sky is a sign of rain, because it is characteristic of the front or east part of a cyclone, and as a cyclone usually travels eastwards, an observer will successively be subjected to the influence of the cloudy and rainy parts of a cyclone before an area of fine weather again reaches him. Again, visibility with an overcast sky is a sign of rain, because the general condition of circulation in the atmosphere shown by straight isobars, during which it is observed, is never persistent for long, bu works up to a cyclone and rain. Visibility with a cloudless sky is a

sign of rain when the cyclone is quickly followed by another. When that is not the case visibility is sometimes the precursor of persistent dry N.W. (*Page* 149) or N.E. winds. As to the 10 A.M. maximum of the barometer, if we look at the barographic trace for May 27th, 1877 [for London], we see that superimposed on the general rise of the barometer between 4 A.M. and 11 A.M. there is a very slight depression. The author's observations for the day are not very complete, but a similar depression is very common, and in many cases he has observed it to be associated with the temporary formation of heavy clouds about that time of day. If this is confirmed by future observation it would point to the conclusion that either overcasting of the sky or the formation of cloud interfere with those statical or dynamical changes which produce the 10 A.M. maximum. The author has pointed out in a former paper that there are critical periods of the formation or disappearance of cloud or fog superimposed on the general cyclone or anti-cyclone character of weather corresponding with the (*Page* 150) hours of diurnal barometer maxima and minima. Cloud produces a small diurnal range of temperature ; at night it reduces the cold, and by day it reduces the sun's rays, so that a temporary clearing up of the sky might make the minimum temperature at almost any hour of the night, and the maximum (*Page* 151) at almost any hour of the day. If ever meteorology is to be a science, it is of the utmost importance to discriminate between the different kinds of clouds, and to determine their position in synoptic maps relative to cyclones and anti-cyclones.

Archibald, E. D.

(*Page* 505.) The hypothesis started by Hill and myself, that the solar radiation varies inversely with the sun spot frequency takes account of the probable effects of such a variation upon the vapour currents throughout the globe with respect to velocity, direction, season, and latitude. According as trades, anti-trades, monsoon or anti-monsoon, prevail (1) at different places at the same season ; (2) at the same place at different seasons, so will specifically distinct effects arise both from the amount of vapour brought, and its conditions of precipitation, to determine which, not only the general conditions introduced by latitude and season, but the local and meteorological functions of the region must be carefully studied. The anti-trade, which in its seasonal shifts north and south traverses the entire temperate zone, should give signs of a secular change in intensity and humidity, corresponding according to the hypothesis, inversely with the sun's spots.

Broun, J. Allan.

(*Page* 126.) Herschel cites Humboldt's statements that the clearing away of clouds was well known to the seamen and pilots of Spanish America. Barnardin de St. Pierre, in his 'Voyage à l'Ile de Reunion,' says : 'I remarked constantly that the rising of the moon dissipated the clouds in a marked way. Two hours after rising the sky is perfectly clear' (April 1768). Faye says the moon has no such effect, supporting his conclusion by the Vigevano register by Serafini, who, however, records the condition of the sky between morning and evening only. M. Schiaparelli finds from this register that the sky was clearest in the first quarter of the moon. Faye's conclusion was faulty owing to the one-sided character of the evidence, and from his neglecting the observations of Mädler and Kreil, Park Harrison and Balfour Stewart. The moon's heat cannot be (*Page* 127) the cause of the phenomenon, as the moon gives no heat, so that it must be explained in some other way.

King, Samuel. *Symons's Meteorol. Mag.*, vol. xiii. (*rsp.*)

(*Page* 176.) He refers to dense fogs at Elswick Lodge. The ponds and ditches were covered with a greyish scum, which seems to indicate the fog was not entirely composed of watery particles. The wind had blown from the north for days.

Lockyer, J. N.

(*Page* 224.) I would ask whether during the night the molecules of aqueous vapour which absorb the blue have not been driven into higher forms, dew being one of them, owing to the reduction of temperature. This would explain the generic differences between sunrise and sunset colours, as also the golden instead of red sunsets which accompany the formation of cloud.

Murray, A. E. *Symons's Meteorol. Mag.*, vol. xiii. (*rsp.*)

[No. for November. It is a newspaper insertion opp. p. 160.]

Col. 3. [There is no numbering in the original.] The clouding which occurs in the front of a barometric depression usually commences in the west, and the clouds at first often assume the appearance of streamers. [His statement is general, but he seems to have W. Europe in his mind.] An attempt was made to test if the moon influences the cloud, by means of observations made at Hastings. [It was assumed that if the thermometer on the ground was not very different from one 4 feet above ground that the sky was cloudy; if there was a great difference that the sky was clear]. For the year 1876 I picked out all the days of full moon, new moon, first and last quarters, and found that the difference between the thermometers was in the following proportions:—Full, 24·7; last quarter, 39·3; new, 41·0; first quarter, 46·6; showing that for that year there was most cloud at full moon, and least at the first quarter. I then combined one day on each side, and obtained the following figures:—Full, 91·9; last quarter, 108; first quarter, 116·3; new moon, 151·5; giving least at new moon, most at full. For 1877 the results were, for one day:—First quarter, 38·9; new, 43·1; full, 49·9; last quarter, 52·5; giving most to the first quarter, least to the last quarter. Including one day on each side, First quarter, 130·1; new moon, 137·5; last quarter, 150·1; full moon, 158·3; giving most to first quarter, least to the full. The two years are utterly at variance, and the impression I arrived at was that the different years would neutralize each other, and that the amount of cloud would prove to be on the average the same for all ages of the moon.

N., J. H.

(*Page* 672.) Boussingault ('Ann. de Chimie,' xii., p. 289) finds from the average of fourteen experiments that the hourly loss of water by evaporation of the leaves of a healthy Jerusalem artichoke for every square metre of foliage is 65 grammes in sunshine, 8 in shade, and 3 during the night. Mint gave off 82 grammes in sunshine and 36 in shade. A grape vine gave off 35 grammes in sunshine, 11 in shade, and 5 during the night. The whole plant had about 138 square metres of foliage, and in sunny weather would lose in 24 hours 48 kilogrammes of water. An acre of beets, it was calculated, could lose in 24 hours between (*Page* 673) 8,000 and 9,000 kilogrammes. Plants that have lost much of their constitutional water may absorb water from an atmosphere saturated with aqueous vapour.

Thomson, Sir C. W.

(*Page* 449.) There is a vast mass of cold ocean water which flows from the south far into the north hemisphere. The explanation of this is simple. For

some cause, not fully understood, evaporation is greatly in excess of precipitation in the northern portion of the land hemisphere, while over the water hemisphere, and particularly its southern portion, the reverse is the case; thus one part of the general circulation of the ocean is carried on through the atmosphere, the water being raised in vapour in the northern hemisphere, hurried by the upper wind currents to the zone of low barometric pressure in the south, where it is precipitated in the form of snow or rain, and welling thence northward in the deepest channels on account of the high specific gravity dependent on its low temperature, it supplies the place of the water which has been removed.

Nature.

Page 385.) In Planté's experiments the electric current in presence of aqueous vapour yields a series of phenomena altogether analogous to the various phases of polar auroræ. If the positive electrode of the secondary pole of the secondary battery is brought into contact with the sides of a vessel of salt water, we observe, according to the distance of the film from the liquid, either a corona of luminous particles arranged round the electrode (fig. 8*), an arc bordered with a fringe of brilliant rays (fig. 9), or a sinuous line, which rapidly folds and refolds on itself (fig. 10). This undulatory movement in particular forms a complete analogy with what has been compared in auroræ to the undulations of the serpent, or to those of drapery agitated by the wind. [If so, then notes on auroræ would afford some information as to the distribution of aqueous vapour in the higher regions]. Planté explains the slow movement or stoppage (*Page* 386) of globular lightning by the movement or repose of the column of moist air strongly electrified and invisible, which serves as electrode. Almost (*Page* 436) every known portion of the south hemisphere (March 28th) has been suffering from a severe and protracted drought.

Nature.

(*Page* 288.) If the upper currents depicted by the Rev. W. C. Ley in his paper are to be regarded as tolerably close approximations to the movements of the cirrus-cloud of a cyclone, it follows that the region of the cirrus occupies a much higher level over the front portion of a cyclone than it does over its rear,—notably than over its north-west quadrant,—a point of prime importance in relation to the theory of storms. Professor Loomis supposes that in great storms the inflowing air escapes by an ascending current, carrying with it a large amount of vapour, which, as it is cooled, is condensed into cloud and rain, and that the heat thus liberated further expands the air.—Montigny (*Page* 292) shows that approaching moist weather increases the intensity of scin- (*Page* 352) tillation of stars (Acad. Sci. Paris, July 16th).—Crova observed that solar radiations were weakest with S. or S.W. winds, and strongest with N. or N.W. winds, the former increasing, the latter diminishing the vapour in the (*Page* 680) air. Dr. Hellmann (in the 30th report of the Royal Meteorological Institute of Prussia) finds that the daily maximum of cloud occurs at Crefeld about, or a little before, sunrise from September to April, whereas from May to August the maximum is from about 11 A.M. to 3 P.M. The monthly maximum which holds also for all hours of the day is December, while the month with clearest skies is September.

* These figures are not reproduced here.

Nature.

(*Page* 178.) Rev. W. Clement Ley : Cloud observation requires a special training of the eye. The classification and nomenclature is highly unsatisfactory, having been framed at a time when the relation of wind and weather to the distribution of barometric pressure was unknown ; and with this relation the form and movements of the cloud are intimately connected. As regards configuration, clouds seem naturally divisible into two groups—those which arrange themselves in layers, whose vertical diameter is small as compared with its horizontal, and those which assume spherical or hemispherical shapes, and this division is related to certain physical conditions of the atmosphere, and of the earth's surface beneath the clouds. The movements of the upper clouds afford most valuable information concerning the distribution and movement of the areas of high and low barometric pressure. It may be sufficient to explain that in the front of an advancing barometric depression there usually extends a bank of the halo-producing cirro-stratus, the exterior edge of which is, roughly speaking, a parabola, the focus of which lies in the line about to be traversed by the centre of the depression. On the right hand of the centre this bank or sheet is abruptly broken, and is succeeded in the rear by local shower-clouds. On the left hand the sky commonly continues overcast, but the cloud-plane gradually descends until little is to be seen but low stratus. A backing of the upper current takes place until after the centre of the depression has passed. In whatever direction a depression is advancing the same characteristic phenomena are observed. Thus changes in the clouds indicate to us probable alterations of wind and weather. While the nimbus which exists in the front of a depression first makes its approach evident by changes in the higher cloud-strata, the process of nubefaction is the converse of this in those local showers which commonly occur on the right hand and in the rear of a centre of depression, and therefore when the barometer is rising, or just about to rise. These latter are developed in an upward direction through the formation of cumulus. The precipitation which occurs in them—always preceded by a change of appearance in the domes of clouds, which assume a soft and cirriform aspect—is attributed to the neutralization of electricities as the summit of the cloud passes into a higher region ; but there are important differences between those cumuli which are likely, and those which are unlikely, to undergo this transformation. A physical explanation is given of the ordinary weather signs derived from the colours of the sky, from visibility, and from unusual refraction. Attention is invited to some unusual types of clouds, especially to a very elevated turreted stratus often erroneously termed cirro-cumulus, occurring with high temperature on the S.W. borders of anti-cyclones, a forerunner of thunderstorms. The formation of the low level stratus, and of the fog which usually prevails in our winter anti-cyclones, seems to be due to a downward movement of the air at a time when the earth's surface is colder than the atmosphere at a slight elevation above it.

Symons's Meteorol. Mag., vol. xiii. (*rsp.*)

[No. for May.]

(*Page* 55.) Alluard's hygrometer is essentially an improved Regnault's. By an arrangement of tubes ether is made to evaporate when wished, so as to cool a flat brass plate. The thermometer beneath the plate indicates the temperature at which dew is observed to form. This is made easier by having an annular surface near, which is not cooled. It is probably the best condensing hygrometer as yet introduced.

[No. for July.]

(*Page* 91.) The questions proposed for discussion at the International Meteorological Congress include the following: Influence of cultivation, of grassing, and of replantation upon the production of dew, on the amount of rain-fall, and on its discharge from the surface of the earth. Origin and nature of dry fogs.

[No. for December.]

(*Page* 167.) In Blandford's theory of cyclones, an essential condition is that the cyclonic area be supplied with an indraught of a saturated current from the S.W. or W.S.W. [His remarks refer to North India, so that this would be also a warm quarter. His theory is in the main the same as Espy's.]

(*Page* 169.) Dr. Koppe's per cent. hygrometer is a Saussure's hygrometer with an arrangement for adjusting the index to the true reading.

1879.

Erskine, St. Vincent, *Journ. Roy. Geog. Soc.*, vol. xlviii. (1879). Read January 28th 1878. (*rs.*)

(*Page* 28.) At Muxango's Kraal [in South Mozambique] in 21° 2′ S. the mornings and evenings were calm and clear, and a sea breeze generally prevailed during the day laden with cumuli.

Hind, J. R.

(*Page* 189.) In B.C. 44 Plutarch and Dion Cassius record that for a whole year the sun was paler than usual, and gave less heat, the air continuing cold and misty.

Ley, Rev. W. C., in *Modern Meteorology*, 1879. (*rv.*)

(*Page* 102-103.) Very little progress has been made on the subject of clouds and (*Page* 103) weather signs. Aratus and Virgil were almost as advanced as some modern meteorologists. But this science is capable of great ultimate achievements. (*Page* 104.) Cloud observation is, in a very great measure, an incommunicable art. Keenness of sight, coupled with the habit of observing phenomena, are the first requisites; to this must be added a training of the eye by practise. By practise, I can now, when only the summit of a cloud forty miles away is visible above the distant horizon, state, with unfailing certainty, whether or not rain is falling from (*Page* 105) the under-surface of that cloud. Similarly, I can detect motions in cirri imperceptible to most observers. Inaccuracy in cloud observations, as regards distance or relative height, is the rule. For example, when cirrus or cirro-cumulus, at a great altitude, is moving in a rapid under-current, while thin clouds nearer to the earth's surface are stationary, or nearly so, most persons say the first-named (*Page* 106) cloud is the lower of the two strata. Forster made this mistake. Artists seldom paint clouds right, so that there is no way of referring to the (*Page* 107) objects by way of illustration except directly. Observers have not settled upon a reliable classification, and the nomenclature is faulty. Every classifi- (*Page* 108) cation must fail which does not take into account the intimate connection between the forms and movements of clouds with other elements. The behaviour of clouds is evidently controlled to a great extent by atmospheric electricity, but we know little about this. A thorough knowledge of all these is essential before we can make a good cloud classification. Clouds may be grouped in two divisions: (*Page* 109) first, those tending to arrange themselves in a horizontal layer, the components of which may be either fibrous and interlacing (which is commonly noticeable when the bed is at a great elevation), or more compactly welded (which is more common when the bed is near the earth's surface), but whose vertical diameter is in any case very small as compared with its horizontal; second, the clouds of

massive spherical or hemispherical shapes, and having a plane base when in the inferior regions. Both exist at all altitudes at which clouds are visible. The first of these divisions comprises essentially the clouds of the night, and the second those (*Page* 110) of the day. Again, clouds of the first division are those of winter, those of the second, clouds of summer. But this rule applies with much fewer exceptions to the lower than it does to that of the higher portion of our hemisphere. Finally (but this rule has many exceptions), clouds of the first division are more common over the sea than over the land. On the west coast of Norway, for example, I have often seen the mainland covered with massive piles of cumulus, while over the sea were only a few streaks of linear cloud. Each little island had a little cumulus poised above it, a larger island a larger cumulus, and so on, the size of the cloud being almost exactly proportional to that of the land surface beneath it. It is even said that a reef when covered with shallow water often has its position marked by a solitary cloud of the cumulus form above it. I here adopt the term stratus for clouds of the first division, and cumulus for those of the second. The most valuable weather signs are derived, not from the former, but from the direction of motions (*Page* 111) of clouds of different levels. Movements of the highest clouds afford information of the highest value concerning the distribution and movements of the (*Page* 112) areas of barometric pressure existing at the time of observation. Here I apply the term 'cirrus' only to the 'curl clouds,' or 'mares' tails,' which float at a high elevation; cirro-stratus to the halo-producing sheet; cirro-cumulus to the (*Page* 113) small white nebulæ which float at the same level as the cirrus and cirro-stratus.

[He then points out how the movements of clouds indicate the positions of areas of high and low pressure; these details more pertinently appertain to barometric pressure and wind, but those which bear upon the distribution of aqueous vapour are given here.]

(*Page* 115.) There commonly exists in front of an advancing barometric depression a great bank of the frozen moisture in the high regions of the atmosphere which we call cirro-stratus. Synchronous observations show that the edge of this bank is commonly curved, and that the curve is, roughly speaking, a parabola, the focus of which lies nearly in the line along which the centre of the depression is about to travel. We do not, however, commonly see this curve in looking at the cloud. What we do see are longitudinal threads, or filaments of thin cloud, at an altitude (*Page* 116) of between 25,000 and 40,000 feet above the earth, and so arranged as to be parallel to each other. Outlying streaks of this cloud often form from twenty to one hundred miles in advance of the main pack, the pioneers of the coming army, and can be examined without difficulty. These threads of ice crystals terminate in most attenuated points which are often curled more or less outwards or upwards, being kept asunder by electric repulsion, the whole thread acting as a horizontal conductor of electricity. As the actual bank comes over us the threads which compose it are seen to be more or less reticulated, forming a filmy sheet or canopy, the structure of which becomes less and less discernible. This is the form of cloud which produces halos. Occasionally, indeed, even from the first appearance of the sheet, we can scarcely discern any structure in it at all; the sky seems simply to become gradually overspread with a milky-looking film of whitish cloud matter. In this latter case we infer that the upper regions are especially humid, and that the crystals being less insulated, consequently do not arrange themselves in definite threads. In any case, as the bank becomes more fully over our station its under surface becomes lower, and is at the same time rendered indistinct by the formation of visible cloud matter in the lower regions of the atmosphere. The commencement of this stage usually coincides with that of the fall in mercurial column, for the (*Page* 117) barometer is often either rising or stationary under the outlying threads

already described. The rain-bringing wind now begins slowly to make itself felt at the earth's surface, the upper clouds cease to be visible at all, for the sky becomes totally covered by a composite mass of condensed vapour, and more or less precipitation at once sets in. I will now describe the movements of that upper current which has brought this canopy over our heads. I will suppose, then, first, that (*Page* 118) depressions are travelling from S.W. to N.E. (which is with us their most common direction), an anti-cyclone lying to the S.E. of our district. First, let us imagine ourselves to be situated actually upon the line which is to be traversed by the centre of the disturbance. Cirrus thread will first appear upon the south-west horizon, and parallel to that horizon. When some of them have arrived at the zenith we shall find them to travel from some point between W.S.W. and W.N.W. A little later, when an easterly wind has sprung up beneath, and when the cloud-bank is getting thick, we shall, if we can catch an opportunity of seeing the higher clouds, find that their current has backed ; that is to say, is now from a rather more southerly point. By-and-by, when the barometer has reached, or nearly reached, its minimum, if we can see the clearing of the sky, we shall find that this upper current has backed so much as to be then moving from a south-easterly point. The cirri will then (*Page* 119) be ranged in lines from S.E. to N.W. Their appearance will, at the same time, have greatly altered ; they will have become much more massive, and their threads or tufts will commonly be seen to point in a more or less downward direction, indicating that a cold and drier atmosphere is setting in below. Now let us imagine that the advancing depression is passing considerably to the N.W. side of our station. In this case the bank of cirro-stratus or its outlying threads have first been visible on the W. or W.N.W., and parallel to that horizon, and the upper current is found to travel from some N.W. point. As the bank spreads over us, while the south-westerly wind springs up beneath, we observe the upper cloud to be less thick and watery-looking than in the description given before. Cirro-cumulus in this case often takes the place of cirro-stratus, which is probably an indication that no great conduction is going on aloft. The rain, if any, falls in spasmodic showers, and when the sky clears it does so far more gradually than at more central stations. Here, too, we shall find that the upper current has backed, but only to a W. or S.W. point, so that when the wind at the earth's surface has veered to W., clouds of every level over our heads will be found to move from nearly the same quarter. (*Page* 120) Again, suppose a depression in going N.E. is leaving us upon its left. In this instance the cirro-stratus bank first shows itself on the S.S.W. horizon, and its motion is from some point between W.S.W. and S. In this case, after the sky has thickened, and a north-easterly wind has freshened with a falling glass, we very rarely get an opportunity of seeing the upper clouds at all ; but when we do, at the time that the centre of the disturbance is nearest to us, we usually observe the upper current to have backed so as to come from S.E. The rain, in this instance, if it extends so far north as our station, is cold, thick, and continuous. As it ceases the clouds remain for a little while low and dreary, the clearing of the sky is very gradual, and when the wind is gone round to N. and the barometer is rising, we commonly see that the main vapour-plane has greatly descended, and that in lieu of the cirro-cumulus, and shower-clouds which are being experienced farther south, we have irregular but level stratus occupying the middle or rather lower beds of the atmosphere. Now, suppose we are in the rear of a disturbance, the central part of which has passed fairly off to the N.E. The sky is either clear or contains fragmentary cumulus and perhaps a few local shower-clouds. Such (*Page* 121) upper clouds as are seen are here commonly either masses or threads of somewhat curly cirrus ; if threads, they stretch from N.W. to S.E., and their motion is, in any case, nearly from that direction, and this coincides, or nearly so, with the line of the isobars. It is a very rare thing to experience a N.W. wind (except

immediately after it has veered to that point) which does not extend to the highest regions of the cloud-bearing atmosphere. When depressions are passing over or near us, the general distribution of high and low barometer is not always such as I have described. But the same rules apply, the winds being shifted. Thus if the depressions are going S.E., we must veer our words eight points or shift our diagram. I shall give one or two illustrations of what I mean. In weather in which we (*Page* 122) know from the previous changes of wind, and better still from our study of the daily maps, that the depressions or areas of rainy weather are travelling from S. to N., the appearance of a thick bank of cirro-stratus in the S.E., moving from some point between S.W. and S. after an interval of fine weather, is often an indication of coming rain, probably heavy, and accompanied by a muggy N.E. wind. On the other hand, if under the same circumstances the first threads of cirrus or cirro-stratus are observed in the W., but are found to travel from the S.W., the rainfall is not likely to reach our station, at least in more than one or two passing showers. Again, let the weather be such as we frequently have in spring, and occasionally in autumn and winter, winds backing and veering between W.S.W. and N., and the weather map showing us that areas of bad weather are travelling from the Scottish coasts towards Holland and Denmark. Let a fine day be succeeded by a watery bank of cirro-stratus in the N.W. travelling from N. or N.N.E., hard weather is to be expected; a blustering westerly wind accompanied by composite cloud-bank will probably veer to a cold N. or N.E. gale. On the other hand, under the same circumstances, let the cirrus appear first in the N.N.E., and travel from a northerly point, we are not then likely to experience more than a few slight showers of sleet or snow, with only a moderate (*Page* 123) backing or veering of the wind. The whole subject is one of great importance in making forecasts. Howard called every cloud from which rain falls a nimbus, but he appears to indicate a twofold division; but neither he nor his successors have told us much of this division. The symptoms of the extensive rainfall become first apparent, as a general rule, in the higher regions of our atmosphere; the cloud-bank begins at a high level, and is succeeded by a composite (*Page* 124) cloud at a lower level. The formation of passing showers is commonly the converse of this process. Almost every one must have observed the formation of a cumulus cloud, probably in the earlier hours of a showery day. Loose shreds of irregular cloudy matter begin to appear, here and there, under the bright blue. They are at first near the earth's surface, commonly in what has been the vapour plane of some stratus in the preceding night. Gradually, as rapid evaporation goes on under the increasing power of the sun's rays, the rising vapour forces upwards the particles above it, which are condensed by the cold of the higher regions into more and more mountainous masses. The under-surface remains level, reposing on the vapour-plane that is precisely at that altitude above the earth at which water passes from the gaseous state to that of mist. Below the cumulus the vapour is rising, but in the invisible state. The general shape of the cumulus is a hemisphere or cone with a surface formed of rounded protuberances. If you look at these you often see them continually tumbling back into the main body of the cloud, which yet continues to swell gradually upwards and outwards. That the older meteorologists were right in attributing this process principally to (*Page* 125) electric disturbance I cannot doubt. The cloud is now an insulated body, more or less highly charged. It repels the opposite electricity from the particles in its neighbourhood, and attracts them to itself, and an invisible rain of such particles is perpetually pouring probably upon all parts of its surface, the general charge of the cloud being retained partly by reason of its spherical surface. Similar clouds have been simultaneously forming in other parts of the heavens, and a thunder clap is heard on the distant horizon. We see in the quarter from which it has proceeded a cumulus or

body of cumuli, the upper surface of which has put on quite a different appearance. It is spreading outwards and upwards in very thin cirrus-like filaments. It has, in fact, risen to such a height as to approach a stratum of gas intensely electrified, and with an electricity opposite to its own, and it is disposing the ice-prisms in innumerable threads, or feelers, spreading their attenuated points through the lofty regions of highly-rarefied air. We look again at the cumulus which we have watched before. Its glowing summit is undergoing a similar metamorphism, becoming softer and more downy than the lower portions of the cloud. Exactly at the same time that this change is taking place, we notice the atmosphere beneath our cloud to begin to be dimmed by the falling rain. The neutralisation of the electricities aloft has permitted the particles of water, hitherto kept asunder by repulsion, to unite and be discharged to the earth in rain. By-and-by little will be seen by the melting (*Page* 126) cloud save a certain amount of cirrus disposed above, and some loose flecks of scud or of soft cumulus beneath. This is the first formation of the typical shower. We have showers and showers; showers which have been formed a long way off, and showers, too, which are so embedded in other cloud forms, that we fail to get a glimpse of their cirriform summits, or even to distinguish the outlines of their sides or base. Showers of thick small rain even fall, in some circumstances, from low clouds of the stratus type, but these clouds also, just before their precipitation commences, lose their definiteness of outline as regards their upper surface, always looking as if they were discharging rain or snow in an upward as well as in a downward direction. But the formation that I have described is decidedly that most distinctive of the local shower in contrast to the widespread rain. Now we all know that the first steps of the formation which I have described are often discernible without being followed by any shower at all. In fine weather, especially in the spring and summer, we often see cumulus forming day after day, attaining its greatest dimensions about the hour of highest temperature, and either dissolving altogether about (*Page* 127) sunset or subsiding into the loose-spread stratus which is scattered at nightfall through the vapour-plane. The colours of the sky are, in many instances, related to the advance or retreat of the extensive nimbus. When cumulus begins to form under those other circumstances which lead us to suspect coming showers, watch its formation and appearance with great care. A very rapid upward development of the cloud while the outline is hard and the base very level is a bad sign, which is intensified if the protuberances of the upper surfaces are seen to toss and roll with much activity. When, as is very commonly the case, there are clouds of other species in the sky, notice these particularly. If there is a good deal of loose (*Page* 129) stratus, the remains of night cloud, around the base of the cumuli, and the latter are forcing their domes far above them, and gradually absorbing or repelling them beneath, the occurrence of showers before nightfall is probable. On the other hand, if there is stratus at a moderate altitude and cumuli are formed still lower down, and the summits of the latter seem inclined to spread out and blend with the stratus as they reach it, while the base of the cumuli become ill-defined and appear gradually melting, the weather is pretty sure to remain dry. In the latter case there is a sort of second cloud-plane in the middle region of the atmosphere, namely, that occupied by the stratus, which serves both to impede the evaporation from the earth's surface by checking the solar rays, and also to conduct horizontally the electricities of the cloud at a very early stage of their formation. The stratus is sometimes of a special kind, never or hardly ever seen before rain. The bold level (*Page* 130) based cumulus is often the precursor of a hail or thunderstorm. It is a very common thing on those occasions, when there is what I have called a second cloud plane at no very great altitude, to see cumulus when its summit reaches the plane, spreading out in very thick opaque folds. To the inexperienced eye these clouds have a somewhat stormy and formidable appearance, probably because they are

rather similar in shape to those far loftier shower clouds whose summits have spread outwards into the cirrus regions of the atmosphere, and the untrained eye recognizes forms far more readily than distance. Yet clouds of this kind rarely or never produce a shower. They may be seen at all times of the year, but especially in spring, particularly in the eastern parts of an anti-cyclone. They are most commonly accompanied with a good deal of haze, and associated with a dry and harsh atmosphere. Luke Howard seems to have intended his term cumulo-stratus to apply to the cirrus-(*Page* 131) crowned cumulus. There is a particular kind of cloud distinctive of special, though rather uncommon, types of weather which would by many be called cirro-cumulus. It is a very high stratus, having numerous protuberances emanating from its upper surface. There is no cirrus about it. Their altitude is rarely less (*Page* 132) than 14,000 feet. They hardly ever occur in our islands, except in summer, and rarely then, unless the temperature is above the mean. They are rather more prevalent in the inland districts than elsewhere. They are usually seen near the western and south-western limits of an anti-cyclone when there happen to be one or more shallow depressions to the southward. They seem to be associated with vast electrical disturbances in the higher regions of the atmosphere, and they are very commonly the precursors of our grandest thunderstorms. This is especially the case when they move with great velocity from a south-easterly or southerly point, while clouds a little below them are flying from N.E. or E. Under these circumstances a single fragment of the cloud of this type, however minute, occurring in a bright sky, will enable an accurate observer to prognosticate thunder. These clouds sometimes disappear before the occurrence of a thunderstorm; the latter then takes place in the daytime, and is formed from the cumulus type already described. But there is a remarkable class of thunderstorms which come on with this kind of cloud. This cloud resembles ordinary stratus in one respect, that it glories in the night. Soon after sunset in a summer evening it often thickens and (*Page* 199) darkens in the S. and S.W., its under-surface being disposed in numberless wavy folds, through which, here and there, shine the highly-reflecting sides of its broken but cumulus-like turrets. Presently the sheet lightning begins to illumine the southern sky, while a light easterly or northerly breeze is felt below. In a few hours the storm is raging. Those of our summer thunderstorms which occur during the night are, with very rare exceptions, of this sort. When passing into the form which produces a shower, this cloud behaves like the ordinary shower-producing cumuli. Their summits run up so as to inosculate in some cases with cirrus at no great distance above them; in other cases their summits become spontaneously cirriform; and this change, probably accompanied by a neutralisation of electricities, is, so far as I have observed, the essential requisite of their precipitation (*Page* 134) in rain. The types of cloud opposite to the rain-bringing clouds are signs of fine weather. One cloud may be particularly mentioned as indicative of no rain. In summer the centres of anti-cyclones often comprise cloudless skies. A little stratus occurs at night, on some occasions at an elevation of from 4,000 to 10,000 feet, and this is developed into cumulus of moderate dimensions during the day. At a great elevation cirrus may often be seen in conoid tufts whose movement is extremely slow. In winter, on the other hand, neither cirrus nor cumulus is common near the centre parts of anti-cyclones, but the sky is rarely clear. A bed of nearly stationary stratus often covers the heavens for many nights and days in succession. This bed is frequently of vast extent, but of very small vertical thickness. Where gaps occur in it we observe a sky totally devoid of every species of upper cloud. Now we infer that there is over every anti-cyclonic area a slight general downward movement of the atmosphere. In the summer the sun's rays dissolve the stratus, (*Page* 135) and the rapid evaporation taking place during the long and hot days sends up the local or scattered patches of cumulus or cirrus. In winter this does

not take place. The vapour in the very high regions of the atmosphere is carried by the descending current towards the surface of the earth; it probably, therefore, experiences a rise of temperature, and consequently does not pass from the gaseous into the visible form. The surface of the earth is, however, losing heat by radiation, and at an altitude of about 3,000 feet or less (often much less) above that surface a temperature is encountered which is low enough to condense the gas into a level sheet of vapour. The remarkable continuity of this sheet I imagine to be due to the fact that wherever a break in it occurs the earth beneath loses more heat by radiation, and the sheet is consequently speedily reformed. The air below is sometimes clear, sometimes foggy. Occasionally over a great expanse of country, and especially in the neighbourhood of our large towns, the atmosphere is obscured by thick fog, and the densest and darkest fogs of London are commonly those which occur beneath this anti-cyclonic stratus; these fogs being, possibly, due not only to the want of horizontal motion in the air, but partly also to the descending currents which accelerate the downward movement of the now water-laden particles of smoke. (*Page* 136) Although strati are usually more prevalent over sea than land, this stratus is much more continuous over the land than over the sea. It is also noticeable that the breaking up of one of these bands of stratus is usually the first sign of a change from settled to unsettled weather. The explanation offered accounts for both these facts. The relative warmth of the atmosphere over the sea in winter prevents the formation of stratus; and again, the cessation of the general descending currents, or the commencement of the ascending currents, necessarily attends the breaking up or the passing off of the anti-cyclone.

Lucas, Joseph. *Symons's Meteorol. Mag.*, vol. xiv. (*rsp.*) [Abstract of a paper read to the British Association.]

[No. for October.]

(*Page* 147.) Changes of temperature in the soil must act upon the contained moisture in the same way as they do on the air above, thereby tending to cause evaporation, or to produce percolation. In an abstract of more than 100,000 observations upon the temperature of the soil, made in the gardens of the Royal Botanic Society, London, 1871-1876, Mr. G. J. Symons observes that the heat-wave commences in March, and spreads downwards till the whole four feet of observation is warmer than the air in September and October, the effect of the preceding cold wave disappearing at four feet by the end of August. In November the cold wave commences, and moves down till the whole four feet is colder than the air by the end of February, when the heat wave begins again.

Morgan, E. D. *Journ. Roy. Geog. Soc.*, vol. xlviii. (1879) (*rs.*).

(*Page* 306.) Along the Urun-daria the atmosphere is so damp, that over the whole region there is a vegetation, consisting of saksaul (*Anabasis saxaul*), tamarisk, brambles, and, where the moisture is still greater, willows and reeds.

Moseley, H. N. (*B.*)

(*Page* 45.) On many mountains the distribution of plants is mainly dependent on the gradual increase of moisture with height (above sea level), as in St. Vincent (*Page* 226) and Ascension. In high Arctic latitudes there is little cooling at night, owing to clouds and mists preventing radiation.

Skertchley, J. A. *Journ. Roy. Geog. Soc.*, vol. xlviii. (*rs.*).

(*Page* 281.) In Wassaw the dry season commences from the end of August, and lasts till November. From December to May there is a short dry season.

Symons, G. J., in *Modern Meteorology* (1879) (*rv.*).

(*Page* 138.) Each cubic foot of the air in the tropics may be said to contain roughly eight grains of vapour at the temperature of 76°. If that air be transferred to these islands, and be reduced to their average temperature of 50°, it must part with nearly half its vapour. When one substitutes for grains and feet, tons and miles, there is no difficulty in understanding why winds from those regions deposit rain on all colder countries over which they blow.

Symons, G. J. *Symons's Meteorol. Mag.*, vol. xiv. (*rsp.*)

[No. for November.]

(*Page* 163.) A lovely spot, embowered in trees and encircled by hills, is usually characterized by a damp, misty, cold, and stagnant atmosphere. These conditions (*Page* 164) are not adapted for vigorous health. Evaporation data would be serviceable in computing the yield of storage reservoirs. Data as to the amount of evaporation would be very useful in connection with sewage irrigation, for it ought, evidently, to be most successful where the air absorbs the largest amount of surplus moisture. Hygrometry is almost identical with the measurement of evaporation, but not quite, because hygrometry considers the amount of moisture in the air at rest, and evaporation is the resultant of the average of a variable number of miles of air of a variable hygrometric condition over a water surface. It is the business of hygrometers to tell us how much water [in the state of aqueous vapour] there is in the air. It is never very great; fifteen grains of water [in the state of vapour] in a cubic foot of air is the extreme, perhaps a trifle beyond the extreme, which ever occurs in this country [England], while it may run down to one grain per cubic foot.

Nature.

(*Page* 269.) Eliot has discovered that a cyclonic vortex when generated in the middle of the Bay of Bengal always travels towards that part of the coast where the wind velocity for the time being is least in comparison with the average velocity for the same place and time of year. This law lends a great deal of support to the theory that a cyclonic vortex is developed through the accumulation, concentration, and condensation of aqueous vapour over a region of comparative calm. (*Page* 299.) Dr. Mann at Society of Arts, January 21st, stated that when solar spots were abundant, more solar energy was thrown out, and this caused a larger amount of the water of the earth to be raised in vapour, which condensed to a greater (*Page* 326) rainfall. Montigny comes to the conclusion that it is the presence of water in greater or less quantity in the atmosphere that exerts the most marked influence on scintillation, and which most modifies the character of it, either when the vapour is dissolved in the air, or when it falls to the surface of the ground in the liquid state, or in the solid state in the form of snow. Prof. Asa Gray in *Am. Journ.* (*Page* 327) *Sci.* showed how the distribution of forests is mainly dependent on the distribution of moisture, and thus explained the great difference which exists in this respect between the eastern and western United States. Afterwards he shows how the distribution and nature of the North American forests are dependent mainly (*Page* 548) on moisture and temperature. Acad. Sci., Paris, March 31st. Colladon: In large hail storms the cumuli forming them are divided into several distinct groups, insulated electrically from each other by sections of cold air resembling smoke columns from several chimneys. The columns of hail the author conceives as a huge descending piston; hence the violent whirling movements of wind near the ground, and the descent of cold, dry, highly-electrified air from the upper regions. (*Page* 523.) Meteorol. Soc., March 19th. Dew, mist, and fog, by George Dines.

He used watch glasses of known area and weight, and exposed them on grass, slate, and a deal board; the two latter were raised a few inches above the grass. A minimum thermometer was placed beside each glass. It is only on rare occasions that an amount of dew exceeding ·01 inch in depth has been deposited upon the measuring glasses, and out of 198 observations in only three has that amount been exceeded. Fifty-eight observations gave the amount of from ·01 in. to ·005 in.; 107 from ·005 in. to ·001 in.; 22 less than ·001 in.; and eight observations gave no dew at all. Dines thinks it may be fairly assumed that the average annual deposit of dew upon the surface of the earth falls short of 1·5 in. There are two kinds of mist, the morning and evening; the morning mist is caused by the evaporation from the water and the moist ground taking place faster than the vapour is taken away; the air becomes saturated, but this does not stop evaporation; the vapour continues to rise into the air, is there condensed, and forms mist, which gradually spreads over a wider surface. The evening mist is produced as follows. The cold on the grass caused by radiation lowers the temperature of the air above it; the invisible vapour of water previously existing in the air is in excess of that which the air can retain when the air temperature is lowered, the surplus is condensed, becomes a mist cloud, and floats in the air just above the surface of the grass. Taken either separately, or combined, the mists appear to be totally and altogether inadequate to account for those dense fogs which at times overspread the country. Dense fogs near the earth are often accompanied by a clear sky above. Dines would attribute these to some cause unknown, by which the whole body of air to some distance above the earth is cooled down, and as a consequence, part of the vapour in that air is condensed, and forms an 'earth cloud.'

Nature.

(*Page* 116.) Meteorol. Soc., May 21st. G. M. Whipple finds that at Kew the amount of sky covered with clouds varies inversely as the barometric pressure between the limits of 29·0 in. and 30·3 in., the variation being most rapid between 29·8 and 30·1 in. Also that above 30·3 in. cloud increases with increasing pressure, attaining the mean about 30·5, and rising above it at 30·6 in. Loomis (*Am. Journ.*
(*Page* 270) *Sci.*, July 1879) examines the paths of storms advancing from the north and from the south. They present different characteristics. In those moving from the south, the southerly winds which accompany them are marked by a greater humidity and velocity, and excessive rainfall. The facts presented by these favour the idea that in a great storm the condensation of vapour is an efficient cause which controls the movements of the winds. The central depression of the barometer seems to be the result of a circulating system of winds, the most frequent cause of which is two or more areas of high pressure at considerable distances, often 1,400 miles from each other—differences of humidity and temperature being important agents in producing, but more especially in maintaining such a system of winds. We require then, to know what are the causes which bring about those areas of high pressure round a region of lower, though still high pressure, and the concentration of moister and warmer air over this region.

Symons's Meteorol. Mag., vol. xiv. (*rsp.*)

(*Page* 89). A. Cruickshank selected six elevated points at distances of about
(*Page* 90) 5, 10, 20, 30, 40, and 50 miles from his station, and by means of these estimated the extreme limits of view in the middle of each day for twenty-one years. The paper concludes with the deductions drawn from the observations. The mean daily distance seen is only twenty-five miles. The mean number of days in the year on which a distance of fifty miles can be seen is ninety. The greatest mean daily

distance seen increases for each month from January to July, and then decreases again from July to January. This monthly increase and decrease in the greatest mean daily distance seen corresponds respectively with the monthly decrease and increase in the humidity of the air. There is no regular relation between the monthly variations in the mean distance seen and the mean monthly amount of cloud in the sky.

[No. for September.

(*Page* 122.) Dr. Grabham, in a paper read before the British Association, observes that the sirocco wind in Madeira is sometimes very dry ; the temperature being 84° and the dew-point below freezing.

(*Page* 124.) H. Courtenay Fox, in a paper read before the British Association, concludes from the discussion of the observations at Greenwich that in the winter (*Page* 125) months cold tends to be synchronous with dryness, warmth with large rainfall ; in the summer months cold tends to be accompanied by much rain, warmth by dryness; and that years of drought tend to assume an average temperature.

1880.

Aitken, J.

(*Page* 196.) Vapour must have some solid or liquid body on which to condense ; the dust particles usually form the nuclei required. When there is much dust in the air, but little vapour condenses on each particle, and they become but little heavier, and easily float in the air. If there are few dust-specks each gets more vapour, is heavier, and falls more quickly. When the air is nearly pure, and only a few dust-particles present, then only a few cloud-particles form, and they are heavy, and fall like fine rain. He concludes that if there was no dust in the air there would be no clouds and no mists, and that the supersaturated air would convert every object on the surface of the earth into a condenser on which it would deposit. When there are many dust-particles they give rise to the light form of condensation which constitutes a fog, and therefore whatever increases the amount of dust in the air tends to increase fogs, and when the dust-particles are not so numerous the cloud-particles are larger, and settle down more quickly. The dust-motes seen in a beam of sunlight are not the active nuclei of fog and cloud-particles, but those which are smaller and invisible. The large motes may be active nuclei, but their number is too small to have any important effect. The products of combustion of gas and fire have great fog-producing power. The products from a clear fire and a smoky one give about equal fogging. Common salt when burned gave an intensely fog-producing atmosphere, but burned sulphur was the most active (*Page* 197) substance experimented on. Smoke descends during a fog because the smoke-particles are good radiators and soon get cooled, and form nuclei on which the water-vapour condenses. Falling smoke indicates a saturated condition of the air.

Archibald, E. D.

(*Page* 394.) [He gives tables showing the variations from mean of cloud for the year, summer and winter at various places]. The tables show that with few exceptions—1. The annual amount of cloud is below the mean at the epochs of the crests of the heat waves, and above the same at those of cold waves ; 2. That the relation is of the same kind, but more marked when the results for the summer season alone are compared ; 3. That the results for the winter show, in several cases, a tendency to vary in the opposite manner. The dates of the crests of the hot and cold waves, as given by Professor Smyth, coincide with and include the principal critical epochs of cloud variation. It would seem that the waves both of heat and of

cold were partially dependent upon watery vapour and its transformations, the heat wave being in part the effect of an excess of sunshine, and the cold wave of an excess of cloud.

Blanford, H. F.

(*Page* 482.) The following is a possible explanation of the alternating oscillation of pressure between the Indo-Malayan region and the Russian plains. Among the best established variations in meteorology which conform to the sun-spot cycle are those of tropical cyclones, and the general rainfall of the globe, both of which imply a corresponding evaporation and the condensation of vapour. Now this variation of pressure evidently has its seat in the higher (probably the cloud-forming) strata of the atmosphere. It is then a reasonable inference that the principal agency in producing the observed reduction of pressure at the epoch of sun-spot maximum is the more copious production and ascent of vapour which may operate in three different ways: First, by displacing air, the density of which is three-eighths greater; second, by evolving latent heat in its condensation; and thirdly, by causing ascending currents. The first and second of these processes do not directly reduce the pressure, but only the density of the air-stratum while they increase its volume. In order, therefore, that the observed effect may follow, a portion of the higher atmosphere must be removed, and this will necessarily flow away to regions where the production of vapour is at a minimum—viz., the polar and cooler portions of the temperate zones, and more especially those where a cold, dry land surface radiates rapidly under a winter sky, such as the great plain of European Russia and Western Siberia.

Burder, G. F. *Symons's Meteorol. Mag.*, vol. xv., 1880.

(*Page* 29.) A rather remarkable hoar frost was observed here [Clifton] on the last two days of January and February 1st. Generally hoar frost is caused by the cooling of the ground below the temperature of the air by radiation. In this case the relatively low temperature of the ground was evidently occasioned by the slowness with which the earth, cooled by a long frost, became affected by the thaw then prevailing. This hoar frost differed also from others in the situations in which it was found, being scarcely less abundant on the roadways, pavements, and gravel-walks than on the grass. The roads were so white as to give the impression of a thin covering of snow. It was also deposited thickly on the perpendicular faces of walls. Another point noticed was its persistence during the day, notwithstanding maximum temperatures of 43° and 48°. The crystals were remarkable for their scale-lik orm.

Croll, James.

(*Page* 521.) But for the sea there would probably be no aqueous vapour, and consequently nothing to protect the earth from losing its heat by radiation. The surface of the ground would then fall to the temperature of stellar space if deprived (*Page* 522) of solar heat. The lowering of the temperature tends to diminish the amount of aqueous vapour contained in the air, and this in its turn tends to lower the temperature by allowing of freer radiation into space.

Croll, James.

(*Page* 191.) The reason why snow at great elevations does not melt is owing to the fact that the heat received from the sun is thrown off into stellar space so rapidly by radiation and reflection that the sun fails to raise the temperature to the melting point. At low elevations where the snowfall is probably greater and the amount of heat less than at the summits, the snow melts and disappears. This is probably due

to the influence of aqueous vapour. At high elevations the air is dry, and allows the heat radiated from the snow to pass into space ; but at low elevations a very considerable amount of the heat radiated from the snow is absorbed in passing through the air into space. A considerable portion of this intercepted heat is radiated back into the snow, and being of the same quality as that which the snow itself radiates, is on this account absorbed by the snow. This heat accumulates in the snow till melting takes place. Were the amount of aqueous vapour possessed by the atmosphere sufficiently diminished, perpetual snow would cover our globe down to the sea shore. The air is warmer at the lower level than the higher, mainly owing to the influence of aqueous vapour ; were this reduced the difference would not be so great. The lower descent of the snow-line on the south side of the Himalayas, and on the east side of the Andes, which are the moister sides, is owing to the fact that the snow-fall is much greater on the moister side. Other things equal the snow would melt at a higher elevation on the moist than on the dry side. The dryness of the air will, in a great measure, account for the present accumulation of snow and ice on Greenland and on the Antarctic continent. These regions are covered with snow because the quantity melted is small, and this is owing to its being prevented from rising to the melting point, owing to the dryness of the air. (*Page* 192) In places like Fuego and South Georgia, perennial snow and ice are caused by the sun's heat being cut off by clouds and dense fogs. The upper surface of the clouds reflects the sun's rays into stellar space, while one-half of the heat which they do absorb is radiated upwards ; the other half which reaches the ground is insufficient to clear off the winter's accumulation.

Dines, G. *Symons's Meteorol. Mag.*, vol. xiv. (*rsp.*)

[No. for January.]

(*Page* 191.) From observations with the microscope on slightly cooled brass surfaces during fogs or mists, I conclude that a good deal of the moisture occurring on surfaces is really a very fine rain, and that the annual deposit of real dew upon the surface of the earth does not exceed one inch. Can any correspondent give a definition of dry fogs? Are they caused by smoke, by some combination of the temperature of the air with vapour, or do they only differ in degree from other fogs.

Ley, Rev. W. C. *Aids to the Study and Forecast of Weather*, 1880. (*rv.*)

(*Page* 3.) The points of cirri frequently point downwards, especially in dry weather. When increasing, these clouds form an interlacing network or sheet of filmy ice-mist, which is often seen over one side of the sky, while the other remains (*Page* 4) temporarily clear. True cirro-cumulus at the highest level often accompanies dry and warm weather. The more massive cloud-forms commonly degenerate into the stratiform descriptions soon after sunset. A peculiar modification of stratus is common under certain conditions. It arranges itself in parallel, but ill-defined, bars transverse to the meridian, which often coalesce so as to overspread the sky. It only occurs with a somewhat tranquil atmosphere, and rarely with a very high or extremely low temperature, and it may be further distinguished by its uniformly sober tints, in which a bluish-grey predominates. It may be distinguished as 'dry weather stratus.' Cumuli may be regarded as a sign of great (*Page* 5) cold in the region above them. Fine weather cumulus has a moderate elevation, and a well-defined rounded surface. Its formation and dissipation is governed greatly by the temperature of the day, the cloud frequently beginning to show itself soon after sunrise, increasing till the hottest part of the day, then gradually diminishing, and eventually disappearing about sunset. This form of

cumulus is comparatively uncommon over the surface of the sea in our latitudes, and it may often be seen from a great distance, marking the position of a coast-line or even of small islands. Showery weather cumulus is remarkable for the rapidity of its formation and disappearance, and for the readiness it displays to pass into other cloud forms. Large and well-developed cumuli are usually called thunder-clouds, from their prevalence in periods of electrical disturbance; but it is worthy of observation that electrical discharges never appear to take place in any form of cloud until its summit has begun to spread outwards or upwards in a more or less cirriform shape, and has exchanged its hard for a soft outline. When cumulus has thus attained a great size it becomes a shower-cloud. In this state it is commonly called nimbus, a term applied to this kind of cloud, as also to the extensive composite cloud-banks, and, indeed, to all forms of rain-cloud. Here the term nimbus will be restricted to the great banks of composite rain-cloud. Other descriptions of clouds have similar modifications to the pocky form of cumulus. Thus cirro-stratus not unfrequently exhibits pendulous banks or wreaths on its under-surface when the temperature of the lower region of the atmosphere is falling, and a colder wind is setting in beneath. Detached fragments of cumulus, particularly when near the earth, are often as irregular in contour on their lower surface as on their upper (*Page* 6) surfaces. Unusual clearness of the atmosphere is commonly taken as a token of impending rain or storm. Now, the removal of the dust particles with which the atmosphere, in settled, and therefore somewhat calm and dry weather, is much charged, is an early indication that either condensation of vapour, or rapid movements of air, or both, has begun to occur in regions immediately to the windward of the observer, and consequently that the latter is nearly within a system (*Page* 7) of atmospheric disturbance. It is commonly said that a rosy sky at sunset presages fine weather. This generalization will fail if taken as a rule; but if we take pains to draw an inference as to the distribution of aqueous vapour in the atmosphere from the colour of the sky, we shall find that the latter frequently furnishes us with information which may be employed as subsidiary to our principles, with much practical utility. The redness of the sun when near the horizon is due to diffraction. Particles suspended in the air, whether dust, smoke, or very minute globules of water, give a red colour to transmitted light. This is the reason why in large towns the sun, both rising and setting, nearly always appears red. In the country the red colour which the rays acquire in passing through a long stratum of air is probably, in large measure, due to water globules forming an extremely fine mist. At sunset, after the evaporation which has taken place during the day, these globules are usually present in large quantity at the time when the air is rapidly becoming cooler, and the sun, therefore, usually appears somewhat red. During the further cooling which occurs in the night, many of the particles are commonly deposited in dew, fewer remain suspended in the air, and the rising sun is therefore less usually red. A red sunrise indicates that after this precipitation the atmosphere still contains a large quantity of water-particles which, after the evaporation about to occur in the next few hours, is likely to form rain-clouds. A grey sky in the evening is commonly caused by the presence of an amount of cloud in the west, which is sufficient to stop the direct rays of the sun, and to allow nothing but diffused light to pass. The behaviour of secondary (*Page* 25) barometric depressions after they have reached the front of an advancing cyclone, seems to be ordinarly determined by the general atmospheric conditions of the district into which they have thus penetrated. If the barometric pressures in front are generally high, and the atmosphere dry, they become filled up, and disappear. (*Page* 26) If, on the other hand, the conditions are less favourable to their ulterior development, they commonly advance as independent cyclonic systems. It is (*Page* 27) probable that an ascending current of atmosphere occurs in the cyclonic

observations, and that this ascending current originates in the simultaneous condensation of water-vapour over an extensive area. The district in which this condensation is most active occupies the point of the cyclone. A little consideration will show that over the north temperate zone, it is on the eastern side of a cyclone that this condition will in ordinary cases occur, since it is on this side that we have southerly winds, while these winds, in moving from warm to colder regions, experience a diminution in their capacity for holding aqueous vapour. A cyclone must, therefore, be regarded as an eddy of spirally ascending air, which eddy is being constantly reproduced on one side of its original position. An anti-cyclone, on the other hand, represents the position of a downward movement of the air, which has lost the greater part of the water vapour in previous cyclonic circulations. In the districts, therefore, near the central calm of an anti-cyclone, the currents take up, instead of precipitating, vapour. This explains why there is no principle of progressive development in an anti-cyclone, and why the cyclones, in their onward course, are not drawn towards the centres of the anti-cyclones, but skirt (*Page* 28) round the extreme exterior of the latter, for it is only the exterior currents of the anti-cyclones which have taken up sufficient water vapour to maintain the cyclonic disturbances. The same hypothesis accounts for the exceptional fact, already noticed, that in our region of the globe, a cyclone on the southern side of an anti-cyclone rarely moves westward, since in this instance the surface winds drawn into the cyclone from the anti-cyclone have not only been descending currents, but have also come from higher latitudes, and are therefore especially cold and dry. The tendency of the cyclones to skirt coast-lines rather than to travel towards inland districts is probably, in some measure, due to the fact that the vapour on which their maintenance depends is drawn principally from the seas. A secondary depression, according to this hypothesis, has its origin in a somewhat local nimbus, or in a local intensification of the general nimbus, and its in-flowing and ascending current is only an imperfect spiral. Again, the same hypothesis throws some light on the tendency which the cyclonic systems exhibit to run in a series—a fact which is difficult to explain, if a cyclone is regarded simply as a revolving disc. When the atmosphere over an extensive district of the globe, say over a portion of the North Atlantic to the westward of our islands, is much charged with water-vapour, the formation of a large nimbus is sufficient to originate a cyclonic system, but a considerable portion of the atmosphere which is drawn into the circulation never reaches the front of the cyclone at all, being left behind, as the cyclone is rapidly developed over another part of the earth's surface; this part of the atmosphere, therefore, falls calm before it has parted with its aqueous vapour, and is in the condition favourable for the propagation of another system. Other and converging lines of evidence in favour of this theory of cyclone and anti-cyclone may be drawn from the behaviour of these phenomena in other parts of the world, but the whole subject may be dismissed with one important observation, that neither the dampness of the atmosphere, as measured by the hygrometer, nor the amount of water collected in a rain-gauge, affords an adequate measure of the amount of cyclonic disturbance which attends a nimbus. The former instrument tells us nothing of the humidity of the atmosphere in general (*Page* 29), and the latter tells us nothing of the thickness of the atmosphere from which the water has been drawn. It is not surprising, therefore, that some of our shallowest cyclones are accompanied by as heavy and general a rain as the deeper systems, especially when it is observed that during sluggish circulations at the earth's surface rapid currents often exist in the higher cloud regions. An objection to the condensation theory of cyclones is occasionally drawn from the fact that, in some cases, both heavy and extensive rainfall is found to occur in the immediate rear of a centre of depression, when travelling eastwards. This may arise from the

inclination of the axis of the cyclone, from which it will occasionally happen that over the wind which blows in the rear of a depression, currents flow in nearly an opposite direction to that wind. These latter currents consequently precipitate their water through the lower stratum of relatively dry air ; the condensation being due to the fact that they are chilled not only by travelling from lower into higher latitudes, but by contact of their under-surfaces with air which is simultaneously (*Page* 30) travelling from still higher latitudes. In the front of a large depression (*Page* 31) at its extreme exterior there commonly stretches a great bank of cirro-stratus. The outside edge of the bank is pretty definite, and its outline in most cases is in rough correspondence with the contour of the advancing isobars. The movement of the upper current which carries the outlying parts of this elevated cloud-bank is often nearly tangential to the edge of the cloud-bank, and nearly opposite to the direction of the wind, which is presently about to spring up at the earth's surface, and in nearly all cases it makes a greater angle than 90° with this wind. As the sheet extends over us the upper current backs very quickly, and continues to do so over the whole of the front half of the advancing system. As the centre advances towards us we commonly observe composite cloud (nimbus), the rain or snow being accompanied by the new current of air belonging to the depression. This cloud bank extends in most instances nearly over the whole front half of the system, both on the right hand and left hand of the centre's path ; but its character differs very considerably on the two sides. If the centre is passing so as to leave our station on its right, the nimbus usually continues until the centre has almost reached its nearest point to us. Then usually, after a sudden precipitation, the sky clears, the cirro-stratus terminating in an upright line, while the wind at the earth's surface begins to veer. The appearance of the sky in the rear of the disturbance, but still on the right side of the centre's course, is usually very unlike that in the front. Comparatively few upper clouds are observed, and the movement of these is commonly observed to be nearly the same with that of the current on the earth's surface. In lieu of cirro-stratus we see fleecy cumulus. Shower-clouds are also common over this district. These latter, in summer, especially in our more inland regions, often take the form of local thunderstorms. In winter, passing squalls of rain, snow, and hail are common. It should be remarked that these showers in the rear of a depression are far more extensive and persistent on exposed coasts and in hilly districts than in inland and more level countries. The atmosphere in this part of the disturbance is in most cases (*Page* 32) clearer or more devoid of haze than in the front. Suppose the barometric minimum leaves the station to the left of its course. Here the nimbus extends over us, and the wind after springing up commences to back, and continues to do so throughout the passage of the disturbance. On this side we rarely experience an abrupt change from a rainy to a clear sky. As the centre passes the higher cloud-forms degenerate into banks of dreary stratus, often attended with an increase rather than a diminution of haze. As the rear of the system approaches us on this side the bolder forms of cumulus are rarely seen, and in place of shower-clouds we commonly notice gloomy-looking banks of condensed vapour in the middle and lower levels of the atmosphere, while cirrus has usually almost or altogether disappeared. In the actual centre of a large depression the sky is often comparatively clear. Shower-clouds are frequently visible, but these have usually here a thin and disintegrated aspect, while cumulus tends to spread itself into stratus, and cirrus lies in broken, though watery-looking patches. The above description cannot be applied without considerable modifications to the smaller or more local systems. These latter are commonly characterized by a more unbroken cloud-bank, gloomy skies (often with rain or snow) prevailing over the central calm, and even to some extent over the extreme rear of the system. The secondaries are especially

marked in most cases by very copious precipitation. In summer local depressions, especially if they are secondaries travelling northwards, are usually associated with heavy thunderstorms. In the front of these last-mentioned systems the cirro-stratus is commonly accompanied, and sometimes almost replaced, by the turreted stratus. (*Page* 33) In summer brilliant weather usually accompanies anti-cyclones, the dry air permitting the sun's rays to have full power. In the central districts particularly, the sky is often nearly or totally devoid of cloud ; at other times light fleecy cirrus, whose motion is extremely slow, is the principal cloud visible. Near the exterior of the system, and especially on its eastern and south-eastern sides, stratus and fine weather cumulus, often accompanied by haze, are the prevailing cloud-forms. At the extreme western and northern borders cirro-cumulus and cirrus are very common beneath which there is fog, occasionally at the sea coast, but rarely at the inland stations. Near the south-western limit of a large and well-formed summer anti-cyclone remarkably cloudless weather often prevails. In winter the aspect of the sky is different. Dry-weather stratus is now the most common form of cloud, occasionally covering nearly the whole of the anti-cyclonic system with an unbroken canopy, the perpendicular thickness of which is very small, though its extent is so immense. Above this, in the higher regions of the atmosphere, there is, in such instances, a remarkable absence of cloud ; while beneath it dense ground-fogs very commonly prevail at the inland stations. In some cases, however, the sky is almost devoid of cloud, or the ground-fog alone prevails. Near the extremity of the system the atmospheric currents usually break up, to a great extent, the canopy of cloud and land-fog. On the eastern and south-eastern limits of the system the appearance of the clouds is often very similar to that which prevails in the same district of an anti-cyclone in the summer ; but banks of the dry stratus are even here more common than true cumulus. Occasionally, however, we experience, as in summer, an exceedingly clear sky on the south-western side of a large anti-cyclone, which in winter is accompanied by intense frost. It may be said generally that the occurrence in any marked degree of the form of cloud which has been distinguished as dry-weather stratus is commonly an indication of an anti-cyclonic movement of the air, and a thoroughly well-trained cloud observer can, in many instances, tell by a glance at the sky whether the wind at his station is anti-cyclonic or cyclonic in character. The following are examples of forecasts based on records of actual conditions :—1. Winter. In the rear right hand of a depression travelling to E. or N.E. Barometers moderately low, rising rapidly ; brisk or moderate N.W. wind ; clear sky between passing showers ; very transparent atmosphere. No tendency to the formation of banks of stratus ; little or no cirrus. As depressions commonly follow each other in a series, and as the direction taken by the last, as well as the absence of the more anti-cyclonic forms of clouds indicates the absence of any distinct anti-cyclone in the west, we expect the N.W. current shortly to fall calm, and to be followed by a fresh bank of cirro-stratus, decline of pressure, wind and rain. 2. Winter. After a day of chilly N. or N.W. winds, depression in the N.E., taking a S.E. course. Wind W. or W.S.W., brisk or moderate ; atmosphere mild ; barometer about the mean or below it, falling rapidly ; cloudy, with flying scud, rough-looking composite cloud-bank, or dense cirro-stratus. The rapid decrease of pressure, in conjunction with the aspect of the sky, and with the previous weather, makes it probable that the right-hand segments of a cyclonic circulation travelling S.E. is about to pass over the station ; N.W. to N. or even N.N.E. gale is, therefore, to be apprehended, with a great fall of temperature, and brisk recovery of pressure. 3. Summer. After moderately dry weather with westerly winds, and barometer about or rather above the mean (northern limit of an anti-cyclone). Barometer about the mean, and steady, or falling but little ; wind S.W. or W.S.W., moderate or light ; overcast, with much low cloud ; temperature about,

or a little above the mean, for the season. The right-hand portion of a depression taking a N.E. direction is probably passing over the station ; no rain, or but slight (*Page* 35) drizzling showers, may be expected ; the wind will most probably veer a little shortly, with a clear sky. 4. Winter. Extreme rear right hand of a large depression going E. or N.E. Calm, clear, and cold ; N.W. wind having died down, and cumuli and shower-clouds disappeared quickly ; sheet of cirro-stratus on S. horizon, edge travelling from W. or S.W. ; barometer below mean, rising, but rise checked somewhat. If the new cirrus-bank had appeared farther in the W., and its edge had moved from a more northerly point, the fresh depression which is probably approaching might have been expected to follow nearly in the wake of the previous system. As it is, however, there is risk of its centre passing on the S. side of the observer, causing a temporary easterly wind, perhaps gale on exposed coasts, with overcast skies, and probably some sleet or snow. 5. Winter. After light winds and dull weather. Barometer much above mean ; totally overcast with low, tranquil stratus, and nearly calm. As this is the central portion of an anti-cyclone no immediate change can be anticipated. 6. Summer. Barometer near its mean, but falling somewhat ; E. or N. breeze ; turreted stratus above, with some cirrus travelling rather briskly from a southerly point. A shallow depression is probably about to pass northerly over the station ; thunder and rain may be anticipated, followed by a light wind from some westerly point. 7. Summer. After westerly winds, with temperature and pressure near the mean. Decided rise of barometer, and very high temperature ; extremely clear and brilliant sky, with very few, and those only very low, soft clouds. Very light W. or N.W. breeze. The central part of an anti-cyclone moving slowly N.E. is likely to pass over the station. A further increase of temperature may be expected, followed probably by bright and hot easterly winds. 8. Winter. Extreme rear of depression moving to S.E. Steady rise of barometer ; wind veering from N.W. to N.N.E. ; hazy, with some dry-looking broken stratus, and no cirrus. An anti-cyclonic system may be surmised to exist over the W. or N.W. Fine and cold, though cloudy weather, may, therefore, be expected, with light winds. 9. Winter. After a period of disturbed weather, with cyclonic disturbances going easterly. Barometer about, or rather above the mean, scarcely falling ; continuous calm for some hours, with persistent and rather heavy rain. The observer seems to be near the centre of a very shallow depression, whose course is not distinctly towards E. or N.E. There is, therefore, a probability that anti-cyclonic currents are forming in the N. Much drier weather with a high barometer may consequently be, with some probability, anticipated.

Ley, W. Clement.

(*Page* 207.) Professor Poëy was one of the first to appreciate the importance of the terminology of clouds being based on the physical conditions to which the varieties are related ; but we know so little of these physical conditions that no (*Page* 210) satisfactory classification can be thus formed. That two distinct beds of clouds—the one at a high and the other at a low level—frequently exist when rain is falling, there is abundant evidence to show ; and perhaps this is especially the case during extensive intra-tropical rains. But observers are at least equally agreed as to the fact that a bed of cirrus may co-exist with a layer of low clouds, either with or without one or more intermediate layers, without the occurrence of rain or snow. And it is equally certain that the majority of passing showers are produced in a single mass of clouds, not necessarily, and perhaps never, homogeneous in structure in the portions near the earth, and in those which extend into the higher regions of the atmosphere, but certainly not divided into two ocularly distinguishable strata.

Parfitt, Edward.

(*Page* 324.) Professor Sayce states that the Accadians supposed all kinds of astronomical phenomena to have an influence upon the clouds.

Rolleston, George. *Journ. Roy. Geog. Soc.*, vol. xlix. (1880) (*rsp.*)

(*Page* 320.) Robert Rawlinson, in a lecture on Meteorology delivered in November 1868, said that evaporation has only an indirect and incidental reference to the land, its real dependence being in the great ocean and still greater sun. The powers of man can never seriously modify cloud in reference to the world at large. (*Page* 348) Professor Koch, following Ebermayer, says a great deal has been written on the evaporation of plants, of which much is intrinsically self-contradictory. Unger says water gives off three times as much vapour as a tree (? surface for surface); Schleiden that the tree gives off thrice as much as water. Koch says such observations and results are of no scientific value; but I consider they are valuable as they are reducible to weight and measure; and also that they have a distinctly appreciable practical value and applicability. Professor Wellington (*Page* 349) Gray tells us that 3,000 square mètres of cabbage leaves will give off as much as a pint of water per diem. It may be objected that the rate of evaporation observed in an isolated mass of leaves or in a single isolated tree does not give us a measure of the rate at which the same process will go on in a wood when the exposed and evaporating surface is relatively so much smaller; and this difficulty, which lies in the geometrical nature of the case, may account for the great discrepancies in the estimates which various writers have given of the amount of watery vapour given off by masses of wood. Pfaff gives 120 kilogrammes as the entire amount evaporated by an oak with 70,000 leaves, each of a square surface of 2,325 millimètres during the period from May 18th to October 24th. Vaillant gives the amount of watery vapour given off by an oak of 21 mètres height, and 2·63 mètres girth at a height of 1 mètre above the ground, as 2,000 kilogrammes on a fine day. Hartig calculates that a German morgen (=2·3895 acres), carrying a thousand trees of nine different sorts of conifers and broad-leaved trees of twenty years' planting, exhale daily during the period of vegetation at least 3,000 lb. weight of water. Professor Prestwich (*Water-bearing Strata*, 1851 p. 118), gives as an estimate for the amount of watery vapour given off by leaves of a tree of average size 2½ gallons per diem. Lawes, in *Journ. Hort. Soc.*, vol. v. (1858), states that three plants of wheat or barley gave off 1½ gallons, 250 grains of water for every grain of solid residuum in the adult plant. Hellriegel gives as his estimate that for the production of 1 lb. of dry barleycorns, 700 lbs. of water, inclusive of the water evaporated from the soil, are all that is necessary, and that other cerealia have their demands limited within somewhat similar proportions. It must, however, be allowed that the cases (*Page* 350) of the drying up of springs as a consequence of cutting down trees are more numerous and better established than the increase of springs by this operation. The explanation of this apparently self-antagonizing or capricious operation of the same primary cause is not far to seek. When a tree is cut down the area once protected by its leaves is exposed to the uncounteracted action of the summer sun, and rainfall may run off it when hardened, just as it runs off an imperfectly thawed surface in the spring, or it may sink away underground by fissures caused by the exposure, and under favourable conditions may give rise to a lake. Generally, one or more of the conditions favourable for this are wanting, and then the diminution of wood goes hand in hand with the diminution of water. Viollet le Duc notices the marked influence of forest destruction in bringing about a diminution of glaciers (*Page* 351), but is unable to say what the connection is. I think the loss of the trees as evaporating agencies is the true cause of the diminution. The cerealia, with their deep roots, are quantitatively pre-eminent for the amount of aqueous vapour

they give off. An area of wood must give off much more vapour than an area of glacier, and would, by the vapour it set free into the atmosphere, save the glacier from wasting. In mountains the influence of forests in increasing rainfall may count for something considerable, whilst in the plains, howsoever well wooded, trees can act only, as do other good radiators, in the way of precipitating, not wind-borne, moving vapour, but simply dew. Any one may observe in a mountainous district how—

> 'The swimming vapour slopes athwart the glen,
> Puts forth an arm, and creeps from pine to pine,
> And loiters slowly drawn.'
>
> TENNYSON: *Œnone.*

The term 'Rauchen der Wälder' is used for the smouldering of the clouds amongst trees. In a lowland or other country frost hangs on such a tree as the birch long (*Page* 353) before it has begun to whiten the ground round it. What is the source of the larger amount of vapour above pines than broad-leaved trees? Does it come from the soil; is it the result of evaporation from the leaves; or is it due in the coniferæ to the action of thousands of points which the whorls of their leaves develop every year? This is a complex question which the present data do not enable us to answer. It is clear the transpiration of the leaves cannot by itself produce this phenomenon, since the transpiration in coniferæ is less active than it is in broad-leaved trees. It follows, then, that if the vapour of water dissolved in such great abundance in the atmosphere enveloping the pines was the result of the evaporation of the trees, this phenomenon ought to be much more striking over the mass made up by the broad-leaved trees than in that made up by the coniferæ, whilst observation shows that exactly the contrary is the actual fact. We must, therefore, ascribe to the soil and to other unknown causes this remarkable property which pines have of attracting watery vapour. If it had appeared from M. Fautrat's tables that this excess of watery vapour was more marked in rainy than in dry times, it would have been easy to explain the fact by figuring to ourselves, the all but infinite area which the fine films of water clothing every needle-shaped leaf of a coniferous tree would make up and offer for evaporation. For the leaves of our common coniferæ wet readily; and it is owing to this property I apprehend that they intercept as much as one-half the rain which falls upon them before it reaches (*Page* 354) the ground, whilst broad-leaved trees intercept but one-third. But, as it appears the coniferæ possess the hygrometric advantage independently of the rainfall, the phenomenon does require some additional information, and may perhaps find it in the theory of the cause of rain proposed by J. A. Rowell in 1839—viz., that electricity increases the buoyancy of aqueous vapour particles. A good conductor would cause rain or dew or mist by drawing off the electricity from the particles; the pointed pine-leaves would very much favour the action.

Smyth, Piazzi. (See *Biby.*)

(*Page* 194.) Angström showed that some of the dark lines at the red end of the sky-spectrum were due to watery vapour. He has found that these lines increase in darkness according to the quantity of vapour present in the atmosphere. This (*Page* 195) band precedes D. A sudden darkening in it denotes a large amount of extra moisture, which is likely to be deposited in rain. The spectroscope is then a ready means for detecting rapid changes in the amount of aqueous vapour in the air. This can be done with the smallest spectroscope. With larger ones the group called 'little *a*, and its preliminary band,' with its myriads of black lines, forms a still more powerful rain-band.

Tait. (See *Biby.*)

(*Page* 340.) Seen from a distance, the mass of cloud belonging to a thunderstorm usually presents a most peculiar appearance, quite unlike any other form of cloud. It seems to boil up from below, and to extend through miles of vertical height. The estimated height, at its lower surface, above the ground varies within very wide limits. Saussure has seen it as much as three miles, and in one case noticed by De l'Isle it may have been as much as five. On the other hand, at Pondicherry and (*Page* 438) Mandli it is scarcely ever more than half a mile. Ordinary auroras are thought to be due to the condensation of aqueous vapour in far less quantity, but through far greater spaces, than the quantities and spaces involved in thunderstorms.

Woeikoff, A. (See *Biby.*)

(*Page* 250.) I think I have proved that, as to what we call the temperature of the air (really that of the lowest stratum), it is, on the equator and a few degrees north and south of it, far more influenced by the yearly distribution of clouds and rain than by the amount of heat received from the sun. The result would be different if we knew the temperature of the whole stratum of air. The heating of the whole surface of the clouds by the sun, and especially the heat liberated by the condensation of water, must give to the higher strata a superior temperature than that they had in the dry season ; in other words, the decrease of temperature with elevation is much slower where the sky is cloudy and rain is abundant in the greater part of the year ; so that in such regions the temperature of the whole air may be higher than in drier climates. I consider water to be the only direct cause of the mildness and uniformity of equatorial temperatures, and this in three ways : (1) By the great heat capacity of water ; (2) by the clouds which interpose a screen between the sun and the surface of the earth ; and (3) by the evaporation of rain-water by the soil and plants. The two latter are especially powerful on the land, even very far from the sea. If it was not for the clouds and evaporation how could we explain, for example, the absence of great heat (hottest month 78·6°) at Iquitos on the Amazon in 4° S., and more than 1,000 miles from the Atlantic ? Where the sky is clear and humidity and rain deficient very high temperatures of the air are attained even at great distances from the equator (10° to 30°), notwithstanding the prevalence of winds from colder regions.

Nature. (See *Biby.*)

(*Page* 220.) Acad. Sci., Paris, December 15th, 1879. On the influence of rain currents traversing them, and the affinity of pines for vapours, by M. Fautrat. On an average the weight of aqueous vapours contained in 1 cubic metre above pines is 8·66 grammes, and on bare ground at the same height 7·39 grammes, showing 1·27 grammes in favour of the pines. Above leafy trees the corresponding numbers are 8·46 grammes and 8·04 grammes ; difference in favour of leafy trees 42 grammes.

Nature. (See *Biby.*)

(*Page* 355.) There are fogs and fogs—from the one extreme of the dry fog of continental meteorologists which merely blur the sky with a bluish-tinted mist and shears the sun of its brilliancy as it nears the horizon, so that the eye can look on its disc undisturbed, to the other extreme of our London fogs. Fogs appear under (*Page* 356) widely different conditions. The last touch in the character of fogs is contributed by smoke, as explained by Sir John Herschel, whereby each particle of soot, acting as as insulated radiant, collects dew on itself, and sinks rapidly through the fog as a heavy body, thus giving to London fogs their yellow, thick consistency, and the suffocating and unwholesome sensation experienced in breathing them.

Nature. (See *Biby.*)

(*Page* 363.) Meteorol. Soc., January 21st, Report. The great local differences in humidity require to be more accurately ascertained than they are at present, not only at seaside places, but in inland districts in their relation to hills and valleys. The council have decided to establish a third set of stations, to be called climatological, at which observations of humidity, clouds, etc., are taken daily at 9 A.M. C. Greaves advocated a more attentive inquiry into the subject of hygrometry. The appearance and disappearance of vapour, its diffusion, its origin in and withdrawal from the vapourous forms, were matters which could now be readily defined through (*Page* 503) the increased supply of good observations. Loomis finds that storms advancing from the Rocky Mountains to the Atlantic pass from a drier to a more humid atmosphere; whereas in Europe those going east pass from a humid to a drier atmosphere.

Nature. (See *Biby.*)

(*Page* 594.) Loomis finds that dry air, even when greatly heated, has but little ascensional force, and that the violent uprising of heated air so frequently witnessed in moist climates is mainly due to the large amount of aqueous vapour with which it is charged. Buchan (*Journ. Scot. Meteorol. Soc.*) remarks that the maximum daily period of the summer thunderstorms in Scotland coincides with the hour when the ascending columns of heated air from the earth's surface are in full activity, and the result is, no doubt, largely due to the circumstance that these ascending masses of heated air develop a charge of electricity as their moisture condenses into cloud. The period of maximum frequency of the winter thunderstorm occurs some hours before and some hours after midnight, or during those hours of the day when the vapour-laden wind of the Atlantic approaches to and reaches its diurnal maximum temperature, and when, consequently, the condensation of the vapour may be expected to reach its daily maximum.

Nature. (See *Biby.*)

(*Page* 48.) Acad. Sci., Paris, November 2nd. Faye says that in paroxysmal eruptions the enormous amount of steam ejected causes volcanic thunderstorms. (*Page* 96) Meteorol. Soc., November 17th. 'Table of Relative Humidity,' by (*Page* 204) Edward F. Dymond.—Lister's experiments show that a single drop of rain develops organisms in sensitive solutions which would otherwise have remained unaltered. Hence germ-producing matter, or the germs themselves, form at least a part of the cloud- and fog-producing dust.

Symons's Meteorol. Mag., vol. xv.

[No. for February.]

(*Page* 2.) Signor Capello finds that the mean of the rain gauges on a tower seventy-five feet high, one on the windward, and the other on the leeward side, is almost the same as that collected by a gauge in an open space five feet above the ground. He concludes that the difference between the higher and lower gauges depends on the force and direction of the wind.

(*Page* 3.) Prof. Poëy first suggested his new classification of clouds at a meeting of the Acad. des Sci. at Paris, in 1863; a fuller paper was read before the Meteorol. Soc. of France, translated into Spanish, and published in Mexico, then developed and printed in English in two or three publications in the United States. It then appeared in the Report of the Smithsonian Institution for 1870, under the title of 'New Classification of Clouds.' Two years after it was further developed and published in the *Annales Hydrographiques* with the title 'Nouvelle Classification des Nuages,' and now it appears as 'Comment on observe les Nuages.'

[No. for March.]

(*Page* 19.) At the Australian Meteorological Conference in November 1879, it was proposed that the mean humidity curve be derived from the means of maximum and minimum of wet and dry bulb thermometers. In this country [=England] maximum and mininum wet bulbs are scarcely ever used, because the maximum of the dry bulb and of the wet bulb not being necessarily synchronous, the difference between them is not always, if indeed, often a true indication of the actual (*Page* 20) difference between the dry and wet at any given instant, and the same argument applies to the minimum. In the absence of self-recording dry and wet thermometers we should have preferred to take the mean of the humidity at 3 A.M., 9 A.M., 3 P.M., and 9 P.M., obtaining the former from one of Nigretti's turnover hygrometers.

The Conference resolved to consider and report on observations to determine the difference in humidity by self-registering maximum and minimum thermometers, and by other methods; and as to the best method of determining spontaneous evaporation.

[No. for April.]

(*Page* 40.) M. Masure read a paper at the Easter meeting of scientific men at the Sorbonne in 1880, entitled, 'Observations on the Evaporation of Water, and on the Transpiration of Plants.' He remarked that even when air was damp (say the humidity not above 80) moisture is often deposited on the earth, that the consumption of water by plants is not wholly due to evaporation from their leaves; that the true amount of evaporation is at present badly determined, but that [it] is really merely a question of the interchange of vapour between the clouds and the earth, dependent on their respective temperatures. This view the author developed in a formula, by which he said that the amount of evaporation could be computed from ordinary meteorological readings. The velocity of the wind is not included in the formula.

[No. for May.]

(*Pages* 49-51.) [Gives criticisms on the skies depicted in pictures at the Salon, Paris, and Royal Academy, London. The artists' names are intentionally not given, the pictures being indicated by numbers and title. The criticisms seem to give very little meteorological information, and to relate rather to artistic success or failure in depicting skies and clouds. Hence the notes are here considered to belong to Art and not to Climate.]

[No. for December.]

(*Page* 160.) If water, or matter containing water, be warmer than the dew-point of air resting upon it, the water will evaporate; and if the air be colder than the water the vapour in the air may become saturated with invisible vapour, and may, in addition, contain globules of water too minute for their weight to cause them to fall to the earth as rain, and which globules, breaking up the transparency of the atmosphere, produce what is called mist or fog. Similarly, but inversely, if warm saturated air passes over ground which is much colder than itself, its capacity (*Page* 162) for retaining, in an invisible form, all the water in it is lessened by its own loss of heat, and the water which it cannot hold invisibly changes into the globular form, and so again we have the transparency of the air destroyed. This second explanation carries with it the identity of cloud and fog, and accords with the cloud formation known as 'pennants' from many isolated mountain peaks, and with the 'table-cloth' of the Cape of good Hope. So much for fogs in general, the damp white normal fog of all parts of the world where fogs exist at all.

1881.

Aitken, John. (See *Biby.*)

(*Page* 312). Mr. Russell's difficulty with regard to fogs in large towns is due to his not taking into account the amount of vapour in the air. The atmospheres of the towns which do not have fogs are drier than that of London.

Aitken, John. (See *Biby*).

(*Page* 384). He describes Coulier's experiments by which he discovered the part (*Page* 385) played by dust in the condensation of vapour. Coulier found the products of combustion to be active as condensers of vapour. This he attributed to unconsumed carbon. He found air after rain and storms less active, and the air of summer less active than that of winter. Coulier also made experiments rendering inactive gases active by means of combustion. He concludes that the explanation of these phenomena has to be found; but seemed to attribute the activity to the heating of the air.

Broun, J. A. (See *Biby*).

(*Page* 558.) Aqueous vapour cannot explain the annual oscillation of pressure, since it is just when the tension of vapour is greatest that the barometric weight is least. The introduction of more vapour into the atmosphere does not make the whole lighter, but heavier; and when we subduct the vapour pressure from the barometric height, we find the oscillation to be greater, not less, than before. It is not easy to determine the vapour pressure from the indications of the dry and wet bulb thermometers; but its amount will not explain the annual law, nor will it explain the independent oscillations in question. I have, however, suggested that the humidity of the air may be in question, and as the oscillations of dryness or humidity of the lower mass are probably related to (*Page* 559) the temperature, the oscillations of pressure may be related to them. I would suggest that the pressure of the atmosphere is affected by gravitation and some other attracting force, such as the electric attraction of the sun, depending upon the varying humidity of the air, and this again depending on the temperature.

Capron, J. R. *Symons's Meteorol. Mag.*, vol. xvi. (*rsp.*)

(*Page* 181.) I began daily records of observations with the spectroscope on the rain-band on July 1st, 1880, and have continued them till now (November). The history of the rain-band may be said to date from the time when Angström's maps of the solar lines were found to present different aspects according to the conditions (*Page* 182) of moisture of the atmosphere at the time of observation, and when that pioneer of spectroscopy proved the presence and absence of certain lines forming bands in the spectrum, more especially a set near D to depend on that condition. No practical meteorological result followed, however, until, as Prof. P. Smith tells us, the subject was first presented to him as a marked feature in sky spectrum at Palermo before and after a sirocco in 1872. [References are made to Smyth's papers on the subject.] In February 1878, appeared vol. xiv. of the *Edinburgh Astronomical Observations*, 1870-77, in which the subject is fully treated. He has contributions in Nos. li., lii. of the *Journ. of the Scot. Meteorol. Soc.* McClean's star spectroscope is a useful instrument for these observations. (*Page* 183) Having obtained the instrument, close the slit, and adjust the focus till the lines in the spectrum are sharp and clear. This should be done on a bright part of the sky. Then point the instrument to the quarter of the heavens which it is desired to examine, and note results, especially as to lines D and their neighbourhood. I generally observe thus at 9 A.M. daily from my laboratory window (looking towards the south); but if time and opportunity allow, three observations at 9 A.M., 1 A.M., and 5 A.M., would be better, varying the parts of the sky tested; and

I examine with the spectroscope elevated about 13°. Prof. Smyth recommends to point as low as you can to the horizon, provided you get transmitted light, and to observe when the sun is neither high nor low. I find in practice 9 A.M. a good time to make observations when only a single one is taken daily, and also that if I get too low on the horizon I am apt to have a false band, due to earth moisture. In observing you will soon remark change in the character of some of the spectrum lines as compared with those seen on a blue sky, with an elevated spectroscope, and moreover, bands of varying intensity are found added to the low spectrum not seen in the higher one. The lines and bands that change their character, or are variable in their appearing, are telluric; either rain-bands or lines, called by Prof. Smyth 'a function of moisture and temperature,' or low sun-bands and lines, distinguished by him as 'a function of dry air and low sun.' The true solar bands remain unchanged. For meteorological purposes generally it will suffice if examination is confined to the principal band on the red side of D. In enumeration of the darkness of the band for the purpose of record, I use from Nos. 1 to 5, as under: 1, means faint; 2, faint to moderate; 3, moderate; 4, moderate to strong; 5, strong. Prof. Smyth uses the enumeration 1 to 10, but I have found a difficulty in distinguishing when so many degrees are used, especially when the intensity of the light varied. Simultaneous observations of the other meteorological instruments should be made, and the circumstances of sun, sky, and clouds noted. Drawings are given of the rain-band as seen by the spectroscope [but are not reproduced here]. They are thus described:—1. Spectrum as seen upon a pure high sky. 2. Spectrum observed January 17th, 1881, 8 A.M. Morning dull, red sunrise; low sun-bands and lines strong; no rain-band. 3. Spectrum observed 24th August, 1881, 8 A.M., showing moderate low sun-bands and lines, and a faint rain-band and lines weak. Rain-band moderate. 5. Spectrum seen December 9th, 1880, 8 A.M. Sun shining through watery clouds; low sun-lines strong. Rain-band strong. 6. Spectrum seen July 6th, 1881: Rain-band everywhere and exceptionally strong, stretching nearly half-way between C and D. Whole spectrum darkened, and obscured. The rain-band's action is hygrometric, and involves the general principle that according to the amount of suspended moisture in the air so [is] its appearance and strength. A faint, or faint to moderate rain-band, may, in some cases only, show an amount of moisture which will remain suspended for some time. A moderately strong, or strong rain-band, represents an excess of suspended moisture which, before long, is sure to descend [as rain]. Prof. Smyth mentions instances, and I have met with several myself where an apparently perfect (*Page* 185) transparent sky showing rain-band has, on a change of temperature, condensed, as it were, into clouds which have poured. A little while since (August) I observed only a faint, or at most a faint to moderate, rain-band, on a beautiful blue sky, studded with white cauliflower innocent-looking cumuli. I predicted wet, and at mid-day meal was twitted with the sunshine and brightness; but sure enough in the afternoon down came the rain. On the other hand, it will sometimes be raining, and yet only a slight, perhaps no, rain-band shows; an effect generally connected with a cold wind, north or east. No rain-band is also sometimes observed when the wet and dry bulb readings only slightly differ; but the explanation of this may be that low earth moisture affects the bulbs, which is not recognised in the sky-directed instrument looking through a thin stratum of it. [He gives some diagrams and observations which show the relation noticed between the rain-bands and rainfall during several periods.]

Groneman, H. J. H. (See *Biby.*)

(*Page* 337.) Messrs. Coulier and Mascart obtained the same results as Aitken in 1875 (*Naturforscher*, p. 400; *Journ. of Pharm.* [4] xxii., p. 165). In my 'Théorie

cosmique de l'Aurore polaire,' I have pointed out the importance of these results on the relation between auroræ and clouds. If the invisible aqueous dust is able to reach much higher regions than terrestrial dust, and if auroræ are in close connection with cosmical matter in a state of extreme division, this cosmical matter is without any doubt enabled to form aqueous clouds in a much higher than the usual level. In *Gæa*, in 1873, it was noticed that the dispersed iron and other vapours derived from combustion in the higher regions must form on cooling a fine precipitate, and may form conducting channels for the auroræ. Secchi, in 1872, noticed the peculiar structure of the cirrus seen during the auroral display, particularly their orientation, which indicated the possibility of such position being due to their magnetic qualities. Microscopic meteorites often occur in hailstones (*Comptes Rendus*, 1872, p. 683).

Preece, W. H. (See *Biby.*)

(*Page* 336.) A confirmation of Aitken's theory of fog occurred in a friend's house at Streatham, on the occasion of the place being filled with steam from the bursting of a boiler. Wherever a cold surface was found the vapour condensed, and left behind it black carbon dust. Nowhere else was this dust found. The snow of London in thawing becomes dirty, owing to the dust and carbon being left behind.

Russell, R. (See *Biby.*)

(*Page* 267.) According to Mr. Aitken's theory, fogs should be common wherever large quantities of fuel are burnt; and all large towns should have urban fogs. Before coal was used Paris did not have more fog than the surrounding country. (*Page* 268) Philadelphia, which burns anthracite, rejoices in a transparent atmosphere. The great coal and iron districts of South Wales are free from fog. A humid atmosphere is not necessary for the production of mist and haze. The frequent long-continued prevalence of blue haze over the whole country, not excepting the east coasts, in the driest east winds of spring, would be a subject deserving investigation. They sometimes extend to a height much above the tops of our highest mountains.

Whipple, G. M. *Symons's Meteorol. Mag.*, vol. xvi. (*rsp.*)

(*Page* 39.) F. N. Shaw is now conducting an investigation on hygrometry and hygrometers on behalf of the Meteorological Society. He adopts Schwackhöfer's hygrometer as his standard of reference. Schwackhöfer concludes that the only correct way of estimating the amount of aqueous vapour in the atmosphere is by chemical methods. Of these methods there are two: analysis by weight, and analysis by volume. Hitherto the first has been the only plan adopted, but it involves much trouble, and gives the average humidity for a lengthened period of time, not the humidity for any given moment. The volumetric method is free from this objection, and may be worked with a comparatively simple apparatus, kept ready to hand, and capable of giving the desired result with accuracy in a few minutes. As to the degree of delicacy required it may be remarked that as 0·1 mm. (*Page* 40) (0·039 in.), of vapour tension represent about 0·013 per cent. of the volume of aqueous vapour in the air, the apparatus should indicate with certainty the change of one-hundredth per cent. or one ten-thousandth part in the volume of air measured. Although Schwackhöfer first constructed his instrument for the particular purpose of determining the humidity of the air at different levels in forests, and comparing it with air at similar heights in the open country, yet he considers that it may be equally well employed in place of the ordinary pschycrometers [= psychrometers] for daily observations at meteorological stations, since it is always ready for immediate use, and without much calculation will give the humidity, the operation occupying ten minutes or a quarter of an hour. The

principle is to measure the volume of air, and repeat the measurement, after the air has had its moisture abstracted by means of sulphuric acid, under the same conditions. In the case of fog the air is slightly heated before it is passed into the apparatus, so that the watery vesicles may be converted into vapour. [A sketch and description of the apparatus is given, and details as to how it is worked.]

Nature. (See *Biby.*)

(*Page* 260). Acad Sci., Paris, January 3rd. 'Facts for the Study of the Formation of Fogs,' by M. André. A high barometer was observed to sink suddenly (with rain) while a fog present disappeared. With a slow rise of the barometer the fog (*Page* 370) reappeared.—The report of the Government Gardens at Rangoon and the attempt made at West African settlements indicate that the vegetation of tropical (*Page* 398) Australia will not thrive in a humid climate.—Dines (*Zeits. f. Meteorol.*, xv., p. 381) estimates the annual dew formation to be about 35·5 millimètres (on grass 26 mm.); at the best 38 mm. Average nightly on grass ·07 mm.—Meteorol Soc., (*Page* 427) February 16th. 'Relative Humidity,' by C. Greaves. The term frequently leads to misunderstanding. He suggests other tables with a more correct denomination. Roy. Soc. Edinburgh, February 7th. Aitken communicated further experiments on the formation of fogs. He found the same results were obtained at very low temperatures (down to 8° F.) as at higher ones. In dry fogs—that is, fogs formed in non-saturated air—certain kinds of fog-forming dust were much more efficient in their action than others. Some, in virtue of their deliquescent properties, formed clouds in non-saturated air; others only acted in saturated air; while a third class (*Page* 490) required the air to be super-saturated. At Mexico the hottest time of the year is the driest, the mean relative humidity for April and May for 1878 and 1879 being only 42.

Symons's Meteorol. Mag., vol. xvi. (*rsp.*)

[No. for May.]

(*Page* 65.) At the Annual Réunion des Sociétés Savantes in Paris Prof. Alluard suggested that Saussure's hair-hygrometers should be graduated in accordance with the indications of the dew-point by one of Alluard's hygrometers occupying the same space. M. Garban read a paper on the rate of evaporation. He experimented with a series of vessels filled with various earths and regularly weighed. The evaporation from chalk was less than that from sand; in fact, the latter appeared to collect most dew and vapour, and also to yield its vapour more readily than any other variety of earth. M. Hébert considers that the fœhn and sirocco are produced when, under the influence of a great Atlantic storm, a current of warm humid air moving rapidly impinges on a chain of mountains which compels it to dilate and to become cooler, and therefore to produce a larger fall of rain. When the air reaches the top of the mountain it contains only the quantity of vapour necessary to saturate it at the low temperature to which it fell during its ascent, and falling down the other slope with a circular or spiral motion, it becomes warmed by the compression, and as much drier as it is warmer. When the point of the system reaches the plain the gyratory descending motion and the centrifugal force jointly produce a diminution of pressure, which gives rise to an internal gyratory ascending current of considerable force, which produces the low pressure found in the centre of the storm. A complete storm thus consists of two parts: an interior region of low pressure, where the air is ascending in conical spirals, and an external area of high pressure and descending spirals. The air in the cyclones becomes rapidly more damp, and thus, while commencing with a very dry air, they finish with (*Page* 57) violent winds and torrential rains. He traces these features in all the cyclones and great storms which occur in the best-known storm regions.

M. Masure read a paper on 'New Researches on the Evaporation of Water and on the Transpiration of Plants.' The abstract supplied by himself differs much from the notes we took. According to the abstract, arable lands influence evaporation mainly by the manure they contain, which renders them more retentive of water. According to our notes he stated that the amount of evaporation could be determined by a formula containing values for (*a*) temperature of the water ; (*b*) temperature of the air ; (*c*) temperature of solar radiation ; (*d*) humidity of the air ; (*e*) velocity of the wind. He then exhibited one of a series of fifty-one charts, on each of which he had placed curves giving hourly observations of all the meteorological instruments which he possessed. The air temperature was taken by a thermometer swung round in the air, and the same thermometer was subsequently used to ascertain the temperature of the water in the evaporators. His observations were made in a garden rather full of plants. He found the temperature of the water at sunrise always below that of the air. He considered that the temperature of stagnant water was different from that in a river where it was tossed about. During the early morning hours he not infrequently found that, instead of evaporating, condensation had taken place on the surface of the water in his evaporators. He found the range of temperature of the water in one day as much as from 49° to 85° F. or 36° F. He had also made experiments as to the amount of evaporation from a tobacco-plant, and found that the hourly amount (*Page* 68) passing off was markedly less when the sky was overcast ; the life and breathing of the plant were, in fact, checked by want of sunshine, the influence of which was greater even than that of heat.

[No. for October.]

(*Page* 155.) Baldwin Latham, in a paper read before the British Association, noticed that the levels of springs rose or fell inversely with the barometric pressure (*Page* 156), and did not seem to be influenced by the hygrometric state of the air, as was suggested by Prof. Hughes.

1882.

Boerner, C. G. (See *Biby.*)

(*Page* 482.) Evaporation commences at sunrise, and continues until the diurnal temperature has attained its maximum, between 2 and 4 P.M. As the decrease of temperature progresses more rapidly from 4 to 9 P.M., than during the remainder of the night, it is evident that a large proportion of the vapour suspended in the heated air during the day is precipitated as evening dew, and frequently by 10 P.M., the deposit on the foliage of trees becomes so copious that it may be heard falling in drops from leaf to leaf. Another period in which dew is copiously deposited is after midnight and at the dawn of day. After 9 P.M. the rate of decrease in atmospheric temperature is considerably retarded, but when the temperature has arrived at its minimum the deposition of dew is augmented. The appearance of dew only in the morning proves that the temperature of the evening was not reduced to the temperature of the dew-point. A hazy atmosphere, or a large amount of invisible vapour, will retard radiation ; hence serene cloudless nights, without deposition of dew, are regarded as indications of coming rain. According to the (*Page* 483) theory of Prof. Henry, the deposition of dew depends upon the stillness of the atmosphere.

Finley, John P. (See *Biby.*)

(*Page* 4.) The place of origin of cyclones is between the belt of calms and the south limit of the trade winds, or say, briefly, in the vicinity of 10° N.—50° W. This region coincides with the zone of constant rainfall, where evaporation is very rapid, cloud formation exceedingly brisk, the air almost constantly saturated with

moisture, and heavy condensation a regular feature of the day. Typhoons form south of the Tropic of Cancer, and in the vicinity of the Philippine islands. The same remarks apply to this region as in the case of cyclones. The general direction of movement of the tornado-cloud is invariably from a point in the S.W. quadrant to a point in the N.E. quadrant. The tornado-cloud assumes the form of a funnel, the small end drawing near to or resting upon the earth. This cloud, or the moving air of which it is the embodiment, revolves about a vertical axis with inconceivable rapidity, and always in a direction contrary to the movement of the hands of a watch. The destructive violence of the storm is sometimes confined to the immediate path of the cloud, as when the small or tail end just touches the earth. While, on the other hand, as the body of the cloud lowers, more of it rests upon the earth, the violence increases, and the path widens to the extreme limit. The tornado (*Page* 5), with hardly an exception, occurs in the afternoon just after the hottest part of the day, and generally disappears before the going down of the sun. The (*Page* 6) hour of greatest frequency is between 3 and 4 P.M. When I speak of the formation of a water-spout at a considerable height in the air, I mean that the (*Page* 7) embodiment of the whorl, or the revolving current of the air, first appears in a dark cloud of minutely divided particles of water, the result of rapid condensation of course in the air, and therefore in the water. Hailstorms are characterized by a strange cloud-formation, and a peculiarity of precipitation unlike any other formation in the category of storms. The cloud from which the hail falls is basket-shaped, with a dark and portentous exterior, a ragged and ominous-looking opening at the bottom; and within a whirling conglomeration of snowflakes, pellets of snow and ice, partly formed, and perfect hailstones. The hail-cloud forms between the currents of the upper and lower regions of the atmosphere, and moves forward in the plane of these currents, either within or just above the upper limit of the lower atmospheric regions, where it finally disappears, and the deposition of (*Page* 9) hail ceases. The tornado is preceded by the formation of a large barometric trough, with a prevalence of northerly and southerly winds at each end. Carefully study cloud development, colour as well as form, also manner and direction of approach. The approach of a cirrus-cloud (perhaps at a height of six to eight miles) from the S.W. is very significant, and is the evidence of the gradual but certain advance of the upper south-west current, which eventually plays so important a part in the development of the tornado-cloud. Clouds are but the embodiments of air currents, yet they are full of meaning. A study of the upper currents of the atmosphere would be impossible without their manifestations, and that, too, in a variety of forms. Wind direction, temperature, and clouds are the proper subjects of observation and thought by the isolated observer [of tornadoes]. (*Page* 10) While the conditions preceding a tornado are forming, the winds north and south of the main axis of the trough cause an increasing contrast of temperature. This contrast increases with rapidity, and the formation of cloud commences in earnest. Huge masses of dark and portentous appearance bank up in the N.W. and S.W. with amazing rapidity. The struggle for mastery in the opposing currents is thus indicated by the gathering cloud formations. The condensation of vapour from the extremely humid southerly currents by contact with the augmenting cold of their struggling opponents continues. It increases rapidly. Finally, when the tenacious hold upon a stable equilibrium can no longer be maintained (which is controlled by the rapidity and extent of condensation), the opposing forces are, as it were broken asunder, followed by the upward rush of huge volumes of air. The outward indication of this event is first shown in the whirling, dashing clouds over the surface of the heavy bank of condensed vapour forming the background. The next stage is the gradual descent of the funnel-shaped cloud from a point apparently just beneath the position of the enactment of the first scene. One pre-

(*Page* 11) monitory sign is excessive sultriness of the air. Other signs equally important and reliable may be found in the development and peculiar formation of the clouds in the western horizon. Sometimes these peculiar clouds extend from the S.W. through the W. by the N. to N.E. More frequently they form in the N.W. and S.W., sometimes commencing first in the former quarters, and then again in the latter ; but in either case they are equally significant. The marked peculiarity of the cloud is found to occur not only in the form, but in the colour and character of development. The sudden appearance of ominous cloud, first in the S.W. and then almost immediately in the N.W. or N.E. (perhaps the reverse in the order of their appearance), generally attracts attention. In almost all cases these premonitory clouds are unlike any ordinary and usual formation. If they are light their appearance resembles smoke issuing from a burning building or straw-stack, rolling (*Page* 12) upwards in fantastic shapes to great heights. Again like a fine mist, or quite white, like fog or steam. Some persons describe these light clouds as at times apparently iridescent, or glowing, as if from their irregular surfaces a pale, whitish light was cast. The dark clouds at times present a deep greenish hue, which fairly forbodes the greatest evil. Again they appear jet black from centre to circumference, or in a change of form this deep-set colour may only appear at the centre, gradually diminishing in intensity as the outer edges of the cloud or bank of clouds are approached. Sometimes these dark clouds, instead of appearing in solid and heavy masses, roll up lightly, but still intensely black, like the smoke from an engine or locomotive burning soft coal. They have been described as of a purple or bluish tinge, or at times possessed of a strange lividness. Frequently dark green, again an inky blackness. One observer says : 'The clouds seemed to be boiling up like muddy water, the upper surface of the cloud reminding me of the incessant eddies or whirls seen in the muddiest portions of the Missouri river.' Others thus : 'I saw two whirling circles of lightish-grey clouds in the west ; they were acting independent of each other, and moved slowly inward toward each other from opposite directions. The clouds were very low, seemed to be on the earth, the wind in contrary directions across the face of the western sky, and surrounding clouds in great profusion.' 'I saw a green-looking cloud in the N.W., surrounded by others not so deep set in colour. Under the cloud from the S.W. there came a large number of little thunder heads, some very dark, but others as white as steam. They seemed to be separated, and running very low. I never saw clouds so low before. Pretty soon they began to go in all directions—some up, some down, right and left, backwards and upwards. I next saw a cloud that looked even all over in colour, and very white, the edges pretty even. It moved remarkably steady, and seemed to be right under the edge of the cloud from the S.W.' 'Two clouds, one from the N.W. and the other from the S.W., seemed to meet, and after meeting passed still lower. Above (*Page* 13) their place of meeting black smoke appeared in very peculiar shape.' The peculiar action of the clouds while they are forming is another interesting and significant feature, which should be carefully watched. There seems to be some strange connection between the almost simultaneous appearance of clouds in the S.W. and N.W. As they approach from opposite directions, they are suddenly thrown into the greatest confusion, breaking up, as it were, into small portions, which dash pell-mell over each other, and in every direction, now darting towards the earth, now rushing upward to considerable heights like the ascension of a sky-rocket, or at moderate elevations rolling over each other in a well-developed whirl. An observer in describing the approach of the clouds from the S.W. and N.W. stated that they 'came together with a terrific crash, as if thrown from the mouths of cannons.' Generally, following closely upon the existence of this condition, the funnel-shaped tornado-cloud appears against the western sky, moving boldly to the front from without this confused mass of flying clouds. As the tornado cloud

advances these scuds continue to play about its top and sides, constituting a (*Page* 15) characteristic feature of the scene. The tornado cloud is, generally speaking, funnel-shaped; that is to say, the lower end is always the smallest. It may appear to be balloon-shaped, basket-shaped, egg-shaped, like a kite or a bulb, or an elephant's trunk, etc. The major axis may be inclined to the perpendicular, but is usually upright. Sometimes it is hour-glass-shaped, and then the tornado is extremely violent. The variations of form are important in a critical study of the tornado. They depend upon the peculiar whirling movements of the air.

Schwedoff, Theodore. *Symons's Meteorol. Mag.*, vol. xvii. (*rsp.*) Paper read before the British Association.

[No. for November.]

(*Page* 149.) Hail comes from very characteristic clouds, sometimes dark, almost black; at other times very bright, but always dense, with clear cut and agitated outlines; we recognize them amongst storm clouds. The same character of clouds is repeated in the falls of meteorites. It is suggested that hail is of extra-terrestrial origin.

Symons's Meteorol. Mag., vol. xvii. (*rsp.*)

Notice of Professor Pöey's 'Les Courants Atmosphériques,' etc. A translation is given of a portion of Chapter I., from which the following remarks are selected:—

(*Page* 99.) We proved in a previous volume that the form of clouds is due to their integral structure, which is inseparable from the physical constitution of the various layers of the atmosphere, where the action of weight, pressure, heat, and humidity undergo constant changes, indicated by the presence of special formations of clouds; that there are two characteristic types of cloud,—the cirrus, formed of frozen particles, and the cumulus, formed of watery ones; all other forms are evolved from these two types; that there exists in the evolution of clouds a scale of complication or increasing speciality from the upper region of the cirrus down to the fracto-cumulus near the surface; that one may regard the atmosphere in a vertical sense as divided into two great regions, each having physical characteristics and meteorological products quite distinct; that usually the Pallio-fractus forms the boundary between these two layers. It is at this intermediate layer, where the watery particles are changing into snow or ice, that the meteorological manifestations are developed. In the regions below this are produced thunderstorms, rain, snow, hail, the easterly trades, surface winds, and optical phenomena dependent on reflection, such as rainbows and coronæ. The general movements of the atmosphere have their origin in the upper regions, as have also equatorial storms, the westerly trades, and optical phenomena dependent on refraction, such as haloes, parheliæ, and paraselenæ. Accordingly heat and moisture prevail in the lower regions, cold and dryness in the upper; and hence the formation and structure of the clouds. In the upper regions the vapour of water is precipitated in the form of ice needles, and in the formation of cirrus; in the middle region in that of snow crystals and cirro-cumulus; and in the lowest region in that of watery particles and of cumulus. The atmosphere may therefore be regarded as consisting of a series of concentric beds of constantly varying properties, and in which the clouds are modified from the cirrus or cumulus to an extent corresponding with their altitude. From the altitude alone it is therefore possible to determine the physical constitution of the stratum and the characteristic forms of cloud, and *vice versâ*. The elements are all intimately related, and the knowledge of any one enables us to deduce the others. When observers are thoroughly persuaded of the truth of these facts they will have a powerful guide in their observations of clouds, they will recognize the importance of employing a nomenclature in harmony with the present state of science, and perhaps they will adopt that which we have proposed.

[To this the reviewer adds]:

(*Page* 102.) Is it possible that the reason that shepherds and fishermen are such good weather prophets is that they study the form and character of the clouds, and that in their rough way they get a truer insight than do those excellent observers who determine that the mean amount of cloud at 9 A.M. is 6·7, and at 9 P.M. 7·1?

[No. for August.]

(*Page* 104.) It seems to follow from the figures given by M. Fautrat that the degree of saturation of the air by moisture is much greater over masses of leafed species of trees than others. [See under 1880 *Nature*, xxi., Notes.] The leafage and branches of leafed trees intercept one-third, and those of resinous trees the half of the rain-water which afterwards returns to the atmosphere by evaporation. On the other hand, these same leaves and branches restrain the evaporation of the water which reaches the ground, and that evaporation is nearly four times less under a mass of leafed forest than in the open, and two and one-third times only under a mass of pines.

1883.

Abercromby, Hon. Ralph. *Symons's Meteorol. Mag.*, vol. xviii. (*rsp.*)

[No. for February.]

(*Page* 11.) There are what are called good and bad hours for clearing; that is to say, that if during a rainy day the sky breaks about 11 A.M. or 2 P.M., the improvement will not last, so that these are bad hours. If, on the contrary, the break occurs about noon or 4 P.M., it is expected that the weather will clear permanently; and these are called good hours of clearing. These are the hours which hold good (*Page* 12) in Scotland, but perhaps they vary in different parts of the country.

Backhouse, T. W. *Symons's Meteorol. Mag.*, vol. xviii. (*rsp.*)

(*Page* 58.) Since 1858 I have registered foggy weather, using as a gauge the distance at which objects can be seen. The scale is as follows:—

Distance visible,	32 miles	Fog, 4
,, ,,	8 ,,	,, 8
,, ,,	2 ,,	,, 16
,, ,,	880 yards	,, 32
,, ,,	220 ,,	,, 64;

and so on in inverse ratio to the square root of the distance visible. The objects observed are any solid bodies in the daytime, and at night ordinary gas-lights. The visibility depends on the distance, not upon the angle subtended by the object; (*Page* 59) size and colour have little influence on visibility. A good deal depends upon height, since the atmosphere is usually clearer high up than low down. I therefore select objects which are approximately of the same height. I found a difficulty in deciding upon a scale. Distance alone would not do, nor a scale of simple inverse ratio, since then there would be no perceptible difference between a moderately clear day and a very clear day. Perhaps a logarithmic scale would be fairer than any, such as:—

Distance visible,	32 miles	Fog, 6
,,	16 ,,	,, 7
,,	8 ,,	,, 8
,,	4 ,,	,, 9

and so on.

Crosby, W. O. *Appalachia*, vol. iii., No. ii. (1883). Read December 13th, 1882 (*rv*).

(*Page* 132.) In East Cuba the sky is usually clear till the sea breeze or N.E. trade-wind strikes the mountains in the middle of the forenoon. Then the watery

vapour is condensed, and clouds (usually cumuli) begin to appear. The cloudiness increases until a continuous cloud-belt is formed, extending east and west as far as the eye can see, but always of very limited breadth. From any moderate eminence, or from a mile or two off the north coast, it can be distinctly seen that the clouds do not extend far south of the summit of the range, enveloping the high peaks and ridges, while through the low passes clear sky appears beyond; but towards the north the cloud-belt may cover the shore, or extend several miles out to sea. On many days, especially in the dry season, the clouds do not form a distinct and continuous belt, and their development is not followed by rain. When the land breeze sets in at night the cloud-belt is carried out to sea, and may often be seen in early morning resting on the northern horizon before it is dissipated (*Page* 133) by the advancing sun. Except during the prevalence of general storms the precipitations take place on the north sides of the mountains, the clouds rapidly disappearing in invisible vapour as they are carried by the trade wind over the heated southern slope.

Dines, W. *Symons's Meteorol. Mag.*, vol. xviii. (*rsp.*)

(*Page* 107.) I have had a meter in use since January. I send a specimen of the results obtained with it :—

Dry bulb.	Wet bulb.	TENSION. By calculation.	TENSION. By meter.
60·5 [degrees]	57·8 [degrees]	·439 [inches]	·302 [inches]
64·5 "	58·8 "	·418 "	·263 "
64·0 "	57·4 "	·387 "	·249 "
64·0 "	56·6 "	·367 "	·223 "
64·8 "	56·5 "	·355 "	·205 "

The method is to take a given volume of air, extract the vapour by means of sulphuric acid, restore the air to its original volume and temperature, and note the loss of pressure. The tension thus obtained is less than that given by the tables; and I have no doubt that further investigation will show that the tension of vapour mixed with air, and not in the presence of water, is less than is generally supposed.

Gladstone, J. H. *Symons's Meteorol. Mag.*, vol. xviii. (*rsp.*)

[This paper is regarded as belonging to 1883. It, of course, strictly belongs to 1863, and when the paper is read in the original publication, it is possible some facts not given here would be entered on account of priority of statement.]

(*Page* 19.) The paper is based on observations on fogs made at about 250 stations. Prof. Tyndall defined a cumulus as the visible capital of an invisible column of saturated air. When on the summit of the Righi one morning last summer [=1862], there lay in the valley of the Reuss a mist like a white sheet on the ground, but as the sun began to exert his power, and a light breeze to spring up, the uniform layer began to break into regular masses, and soon far beneath us there stretched a cirrus-cloud, identical in aspect with those one often sees in the (*Page* 20) highest regions of the atmosphere. It is difficult to draw a line of distinction between fog and mist. The value of meteorological returns depends on this, and it appears that what one observer calls fog another describes as mist or haze. Mr. Cunningham suggests that when a pole, painted vermilion, placed at 100 yards distance, is rendered invisible by mist, such mist should be called a fog. Some months are marked by fogs more than others. For instance, along the south coast of England, February and September are comparatively free, while January and June are foggy months. November is notorious for fogs in London, but does not seem to deserve that character elsewhere. Some years are much more visited by fogs than others. For instance, 1861 was freer than 1858 along most parts of

the coast. England does not deserve that pre-eminent character for mistiness which is attributed to it by the popular imagination of the Continent. A fog is more uniformly distributed over the surface of the sea than on the adjoining coasts.

Robie, David. *Symons's Meteorol. Mag.*, vol. xvii. (*rsp.*)

[No. for January.]

(*Page* 184.) In past generations it was the common opinion that the rain-clouds were supplied with their water from neighbouring seas. The old agricultural reporters of the counties often spoke of a certain quantity of rain coming with the west or south-westerly wind from the Atlantic Ocean, and again so much being brought by an east wind from the German Ocean. They obviously attached little significance to what is termed a drying wind or a sunny day, or perhaps thought that the evaporation from the soil in the shape of aqueous vapour passed into space. The washerwoman, though a capital judge of a drying day when suspending her wet clothes, would take no account of what became of the moisture which disappeared in the process of drying. From observations with rain and (*Page* 185) Dalton gauges made at Bedford in 1882, I find that the water in the rain gauge measured 28·42 in., while the amount in the Dalton gauge, representing the amount which percolates the soil, was 14·50 inches. Hence almost one-half of the rainfall passed upwards into the atmosphere in an imperceptible form. The percentage which the percolation amounts bore to the rainfall in the several months was—January, 83; February, 50; March, 68; May, 54; June, 20; July, 51; August, 8; September, 40; October, 46; November, 67; and December, 94. (*Page* 186) Dalton gauges of various depths are in operation at Rothamsted, from which it is found that the moisture in the soil is drawn up from considerable depths. One gauge is five feet deep.

Tomlinson, Charles. *Symons's Meteorol. Mag.*, vol. xviii.

(*Page* 117.) Pictet made observations on the temperature at 5 feet and 79 feet (*Page* 118) above the ground in 1779. He found that the lower thermometer marked a lower temperature than the upper during the night. The difference was observed at all seasons during moderate and in cloudy weather; only in the last case the effect was much less appreciable. When the sky was completely clouded or fog prevailed the difference disappeared, both thermometers reading alike. Prevost, in 1772, correctly expounded the action of clouds in limiting radiation.

Symons's Meteorol. Mag., vol. xviii.

(*Page* 18.) We regret that no systematic records have been kept of the amount of fogs. We can only recall three short papers on fog distribution—two in the British Association Reports for 1861 and 1862 and the abstract of Dr. J. H. Gladstone's lecture to the Royal Institution on 'Fogs and Fog Signals.' [The latter is reprinted, and notes from it are given separately under Gladstone.] What is the (*Page* 21) best mode of determining the density of a fog? Dr. Gladstone mentions Mr. Cunningham's suggestion of a vermilion-coloured post. Why vermilion? Surely black and white would be a better contrast. The visibility of the pole will depend upon the background. The background should be uniform. Hence we think a broad board painted with stripes would be better than a pole. Further, the pole should face the south at all stations. In towns a distance of 100 yards may not be available, and we do not think so great a distance is needed. It appears to be desirable and practicable to obtain something more precise than a mere record of fog or no fog, according as one special object is or is not visible, and we should like to see an apparatus which by day or by night would indicate no fog, slight fog,

moderate fog, dense fog. Mr. Cunningham's pole cannot be assumed to be more than 4 in. in diameter, and such a pole at the distance of 100 yards would subtend the very small angle of 3′ 49″. The measure of obscuration depends on the angle subtended by the object, and a black line 0·4 in. broad on a white board at a distance of 30 feet would subtend the same angle of 3′ 49″. As Dr. Gladstone says that such a pole as has been proposed seems to correspond with the ordinary definition of fog, we might accept its equivalent or (0·27 in.) $\frac{1}{4}$ in. at 20 feet as the breadth of No. 1 on the fog scale ; and the subsequent numbers might be multiples of it—viz., $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, and 4 in. Our board would be horizontal, so that all parts of the (*Page* 22) scale should be under identical conditions, and it should, we think, never be less than 5 nor more than 10 feet above the ground. The scale figures should be painted above the lines. At night fogs may be gauged by street lamps or by means of small lanterns fitted with a composite candle and having a groove into which from one to four thicknesses of coloured glass could be dropped. In the densest fog such a light without any glass would be invisible at about 30 feet (perhaps at 20 feet, but we are not sure), and the density of the fog would be determined by placing the lamp at a distance of 20 feet with all the thicknesses of glass superposed, and removing them one by one until the light becomes visible ; *e.g.*, if when all four were in the light could be seen, there would be no fog ; with three in it would be No. 1 ; with two, No. 2 ; with 1, No. 3 ; with none in, No. 4 ; and if the naked light could not be seen, it would be a maximum fog, or No. 5. Of course (*Page* 38) all the lanterns must be alike and the glasses of equal tints.—The Rev. W. C. Ley has issued a circular of a scheme for the observation of the upper clouds, in which he suggests the outlines of a cloud classification. He objects to the terms cirro-stratus and cirro-cumulus as leading to confusion. In point of structure the clouds usually called cirro-cumulus belong essentially to the higher strati forms, consisting of nubecules separate or partly coalescing, occupying a layer of atmosphere of very small vertical thickness, but of very great horizontal extent, and they are not formed in nature by the processes which are productive of clouds either of the cirrus or of the cumulus type. The different varieties of cirriform clouds are described, with the symbols proposed for their designation. By means of a regular staff of observers information may be obtained as to the forms of the higher clouds, which will double the value of existing storm warnings ; enable an isolated observer to plot out the general distribution of atmospheric pressure, and of the weather existing in the British Islands at the time of observation ; form a forecast of what such distribution and the weather will be in the ensuing twenty-four hours ; and furnish early information of coming storms. Mr. Ley's nomenclature seems to be too complicated for cloud observers.

AQUEOUS VAPOUR.

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